JOURNAL OF THE AMERICAN WELDING SOCIETY

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Tentative

PROGRAM

Annual Meeting of the

AMERICAN WELDING SOCIETY

APRIL 27, 28, 29, 1932

ENGINEERING SOCIETIES BUILDING
33 West 39th Street, New York

IMPORTANT NOTICE

Members and their guests are requested to register
All Sessions start promptly as scheduled

Wednesday, April 27, 1932

Morning

BUSINESS AND TECHNICAL SESSIONS

10:00 A.M. to 10:30 A.M., Room 2, 5th Floor, Business Meeting, E. A. Doyle, President, presiding

Report of President, Report of Tellers' Committee, Election of Officers.

10:30 A.M. to 12 Noon, Room 2, 5th Floor, Technical Session, E. H. Ewertz, Past President, presiding.

SHIPBUILDING

"Welding in the Construction of U. S. SS. *New Orleans*," by Captain J. O. Gawne, United States Navy.

"Experimental Determination of Stresses in Fillet Welds," by L. C. Bibber, Bureau of Construction and Repair, Navy Department.

"Welded Barge Construction," by Gordon G. Holbrook, General Superintendent, Federal Shipbuilding and Dry Dock Company.

Afternoon

TECHNICAL SESSION

2:00 P.M. to 5:00 P.M., Room 2, 5th Floor, F. P. McKibben, Senior Vice President, presiding.

"A Study of the Transformation Points of Fusion Weld Metal," by E. R. Hensel and E. I. Larsen, Research Laboratories, Westinghouse Elec. & Mfg. Company.

"Cause and Cure of Intercrystalline Corrosion in Austenitic Steels," by John A. Mathews, Vice-President, Crucible Steel Company of America.

"Welding Duralumin," by H. S. George, Research Engineer, Union Carbide & Carbon Research Labs.

"Welding Wrought Iron Pipe," by James Aston, A. M. Byers & Company.

Evening

BOARD OF DIRECTORS' MEETING

6:30 P.M., Dinner Meeting, Board of Directors.

Meeting of Board of Directors of AMERICAN WELDING SOCIETY. Appointment of Committee Chairmen and other Officers. Committee reports. Plans for the coming year.

Thursday, April 28, 1932

Morning

TECHNICAL SESSION

9:30 A.M. to 12 Noon, Room 2, 5th Floor, C. W. Obert, Chairman, Welding Conference Committee, presiding.

"Spot Welding," by Carl De Ganahl, President, Fleetwings, Inc.

"Arc, Gas and Resistance Welding of Pressure Vessels," by H. LeR. Whitney, M. W. Kellogg Company.

"Production Welding of Light Gage Metal Specialties," by representative of Servel Company.

"Welding of Extruded Metal," I. T. Hook, Research Engineer, The American Brass Company.

Afternoon

TECHNICAL SESSION

SYMPOSIUM: "DUCTILITY IN WELDS"

2:00 P.M. to 5:00 P.M., Room 2, 5th Floor, F. T. Llewellyn, Past President, presiding.

Papers by—C. A. Adams, Harvard University.
E. Chapman, Lukenweld, Inc.
E. R. Fish, Hartford Steam Boiler Insp. & Ins. Co.
T. N. Greene, The Linde Air Products Co.
C. J. Holslag, Electric Arc Cutting & Welding Co.
C. H. Jennings, Westinghouse Electric & Mfg. Co.
H. F. Moore, University of Illinois.
D. Rosenthal, University of Brussels.
C. L. Waddell, Worthington Pump and Machinery Corp.

Evening

ELEVENTH ANNUAL DINNER

6:30 P.M.

The dinner has been arranged as a stag affair. An unusual educational and entertainment program has been provided. Price, $4.00. Hotel New Yorker.

Friday, April 29, 1932

Morning

TECHNICAL SESSION

9:30 A.M. to 12 Noon, Room 2, 5th Floor, J. J. Crowe, Director, American Welding Society, presiding.

"Modern Spot and Relief Welding," by P. W. Fassler, Manager, Electrical Welding Div., Fisher Body Corporation.

"Machine Gas Welding," by J. L. Anderson, Air Reduction Company.

"Pipe Welding for a High Pressure Steam Power Plant," by E. B. Severs & W. P. Gavit, United Engineers & Constructors, Inc.

"New Aspects in Pipe Welding," W. P. Curley, N. Y. District Manager, Tube Turns, Inc.

Afternoon

MEETINGS OF
STRUCTURAL STEEL WELDING COMMITTEE
AMERICAN BUREAU OF WELDING

2:00 P.M. to 3:00 P.M., Room 2, 5th Floor, Meeting of Structural Steel Welding Committee, L. S. Moisseiff, Chairman, presiding.

Outline of program of future investigations.

3:00 P.M. to 5:00 P.M., Room 3, 5th Floor, Meeting of American Bureau of Welding, C. A. Adams, Director, presiding.

Review of progress. Election of officers. Plans for the coming year. Special report of Fundamental Research Committee.

Welded Drums

Attention has been called to an omission in the article beginning on page 9 of the January issue, entitled "Rules for Fusion Welded Construction of Boilers and Pressure Vessels." In the Editor's Note which precedes the reprinting in the fourth paragraph, the statement is made: "The rules for welding steam boiler drums are, as above noted, identical with Class I Pressure Vessels." There is a slight but important difference between the requirements for boiler drums for Class I Pressure Vessels in that all of the welded joints, both longitudinal and circumferential, of a boiler drum must be X-rayed, whereas in a Class I pressure vessel all longitudinal welded joints and one circumferential welded joint need be X-rayed or where there is no longitudinal joint, only one circumferential joint is required to be X-rayed.

Ohio State Conference

The first welding conference of Ohio State University was held in the Industrial Engineering Building on February 25th and 26th. This meeting was arranged in cooperation with the manufacturers and users of welding equipment and materials. The program included in addition to addresses of welcome and announcements, the following welding papers:

Thursday, February 25

1:30 P.M.

"Construction of Welded Machine Bases," E. W. P. SMITH, Consulting Engineer, The Lincoln Electric Co.

"Theory and Practice of Oxyacetylene Cutting," T. M. HAMER, Field Engineer, The Air Reduction Sales Co.

"Welding in Railroad Shops," CLAY ROBERTS, Welding Engineer, Pennsylvania Railroad.

7:30 P.M.

"Spot, Seam, Butt and Projection Welding" (Illustrated), M. L. ECKMAN, Research Engineer, The Federal Machine and Welder Co.

"Welding Overland Pipe Lines by the Lindeweld Process" (Illustrated with Motion Picture Films), W. S. WALKER, Development Engineer, Linde Air Products Co.

Friday, February 26

9:00 A.M.

"Fatigue and Tensile Tests of Welds and the Relief of Residual Stresses," CHARLES H. JENNINGS, Research Engineer, The Westinghouse Electric and Manufacturing Co.

"The Welding of Copper and Copper Alloys," W. C. SWIFT, Service Engineer, The American Brass Co.

Short Talks

"Hard Surfacing," HAYNES STELLITE Co

"Welding of Stainless Steel," REPUBLIC STEEL CORPORATION.

1:00 P.M.

"Arc Welding of Steel Buildings and in Manufacturing," J. G. RITTER, Welding Engineer, The Westinghouse Electric and Manufacturing Co.

"Arc Welding," H. J. BABCOCK, Industrial Welding Specialist, The General Electric Co.

"The Use of Stock Fittings for Welded Piping," H. J. BARTLETT, The Crane Co.

There were demonstrations by manufacturers of welding equipment and supplies who exhibited and demonstrated the latest developments in welding apparatus.

SECTION ACTIVITIES

BOSTON

On Friday evening February the nineteenth, the Boston Section held its regular monthly meeting at the rooms of the Engineering Societies. The meeting was sponsored by the Westinghouse Electric & Manufacturing Company, and Mr. R. Kraus, Supervisor of Welding Inspection with that company, gave a very interesting talk on the many ways of holding down costs in production arc welding, dealing particularly with manual welding. Many slides were used to supplement the talk.

The March meeting of the Section will be held Thursday, March the tenth, under sponsorship of John A. Roebling's Sons Company. Four reels of motion pictures showing construction of Washington Bridge across the Hudson River, and two papers on arc welding as applied to ship construction are planned for the program. The meeting will be of unusual interest, and a large attendance is expected.

CLEVELAND

The monthly meeting of the Cleveland Section was held February 17th in the C. E. S. rooms, Cleveland. The speakers for the evening were W. T. Rogerson, who read a paper on The Welding of Aluminum Using Oxyacetylene and Metallic Arc Welding Processes. Following Mr. Rogerson, D. I. Bohm of the Aluminum Company of America gave a talk and told of the progress being made in the Resistance Welding of Aluminum. The discussion following the papers was highly interesting. The attendance was about seventy-five.

CHICAGO

The welding of structural steel for buildings was the subject of the regular meeting of the Chicago Section, which was held Friday evening, February 5th. The subject was introduced by the presentation of motion pictures showing the welding on the office buildings in Boston, Los Angeles and Dallas. These films were supplied through the courtesy of the General Electric Company and were supplemented by comments and discussion by Mr. W. B. Frackelton of the Chicago office of the General Electric Company.

Following the showing of the motion pictures, Ernest Lunn, Consulting Engineer, Chicago, gave a summary of the important features of the report of the Structural Welding Committee and discussed the conclusions which were drawn in this report with reference to the design values of welded joints, the comparative merits of different types of joints investigated by the Committee and the significance of qualification tests in structural steel welding.

The application of welding to home building was covered in an illustrated talk by Henry Dubin of the firm of Dubin & Eisenberg, architects, Chicago. Mr. Dubin recently finished the construction of a home in one of the North Shore suburbs and in his talk he showed a number of the advantages of welded construction in residences. The work which he has already done involves the use of many ingenious ideas, but Mr. Dubin left a very strong impression that he anticipates a great deal of new progress.

EMPLOYMENT SERVICE BULLETIN

SERVICES AVAILABLE

A-156. Welder with eight years' experience desires position in the East. Can give references. Experience includes arc welding including overhead—eight years. Two years atomic hydrogen welding and one year acetylene welding.

A-160. A graduate of a leading University, A.B. Chemistry, M.S. Metallurgy (1931) wishes to specialize along the line of welding. No experience in practical welding. An American, 32 years old, single. Salary and the location—secondary matter. Available on short notice.

POSITIONS VACANT

V-52. Desire welding engineer who is qualified to design and incorporate new improvements in our present welder and who is capable of solving difficult problems. Must have had some experience with automatic welding and know welding wire and the type best suited for all classes of work. Desire man between the ages of 30 and 40.

Use of Welding in Plate Fabrication

By T. F. BRIGHT

†This paper was presented at the January 8th meeting of the Chicago Section, A. W. S. by T. F. Bright, Structural Engineer of the Western Gas Construction Company.

MY FIRST thought on this subject was that story, probably familiar to some of those present, of the swaggering, bragging tough, shouldering his way to the bar of an old-fashioned saloon and after gulping down his first drink, announcing that he could "clean-up" anyone in the town. Silence greeted his outburst. After the second drink, he enlarged the scope of his contemplated activities and stated that he could "bust" anyone in the county. Again silence was his only answer. Two or three more drinks enabled him to shout that he could "take" any man in the state. Immediately the smallest man in the house proceeded to take his measure. Upon being brought-to, the bully's first words were, "I reckon I tried to cover too much territory."

This subject, if treated properly and completely, would undoubtedly fill a large volume and a paper such as this can hope to deal only meagerly with possibly one or two phases of the subject matter.

During the past few years I have had the privilege of attending a number of conventions and meetings of various technical societies and listening to a great many papers and lectures dealing with some phase of "Welding," only to be impressed with the attitude of the majority of the speakers, which invariably seemed to be that they had solved all of the, may I say, mysteries, of the art and proceeding to enumerate to their pupils, the audience, their findings or discoveries, which in most cases were details which had been known to the greater part of the gathering and in some cases forgotten by them as ancient history.

Invariably I have left the majority of such meetings with a rather disappointed feeling, having learned nothing of value or else a theory which was impractical when applied to my own problems.

For this reason, I hesitate to address this meeting tonight, for I do not claim to be an expert on welding; rather I feel more like the traveler, lost in a forest, seeking the open road. To me, the many sides of welding and its great possibilities are awe-inspiring and the points with which I am familiar seem so few compared to the many which are as yet unknown to me.

My one thought in coming before you is not that of bringing to you a theory or practice, new and unknown, to all except myself, something that I am to give you and which you are to take and apply to your various problems, but rather to promote a general discussion on several points which have been brought to my attention.

Products Manufactured

May I digress from the subject matter of this paper long enough to state that the Western Gas Construction Company, for whom the speaker has charge of welding operations, is probably the oldest firm in this section of the country dealing in the fabrication, by welding, of a most varied line of products.

This company was first formed in the year 1888 and designs and manufactures, at their plants in Fort Wayne, Indiana, Gas Plant Apparatus and Specialties, a partial list of which includes

A B C Generator Grates
Napthalene Removal Apparatus
Condensing Equipment
Carburetted Water Gas Plants
Blue Water Gas Plants
Rotary and Tower Scrubbers
Tar Extractors
Waste Heat Boilers
Gate, Butterfly, Angle and Mushroom Valves
Water Seal Holders
Waterless Holders
High Pressure Holders
Liquid Purification Plants
Oxide Boxes or Purifiers
Breeze Collectors
Ammonia Concentrators
Cooling Coils
Steam Accumulators
Oil Foggers
Industrial Buildings
Storage Tanks, and
Welded Steel Piping,

of which list, the majority of the fabrication is accomplished by welding. Those few products, which at the present time are not welded, are being studied con-

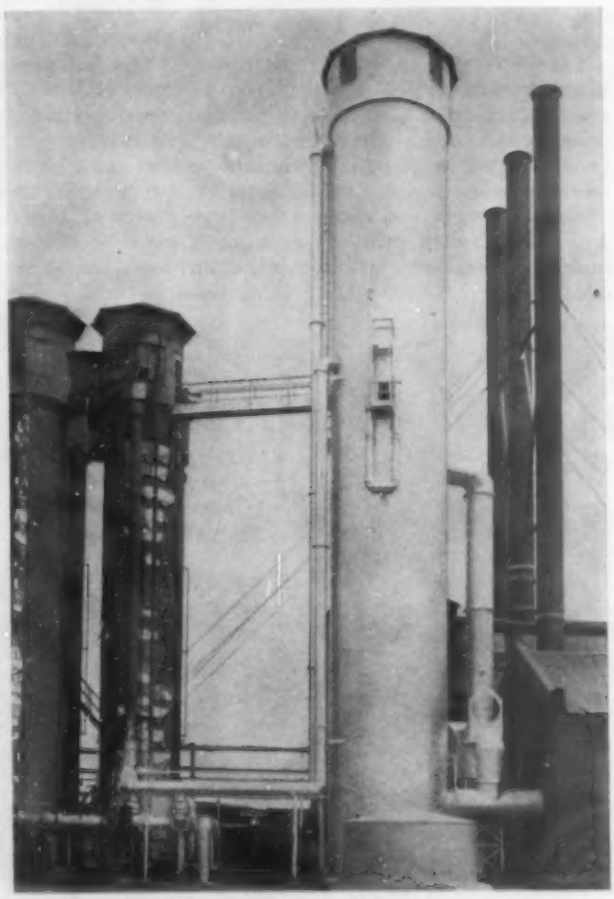


Fig. 1—All Welded 16'0" Diameter by 104'2" High Absorber-Actifier

stantly, with the view in mind of their welded fabrication at an economical cost.

Although the speaker has been associated with the company only during the past four or five years, he has records of at least partial fabrication by welding of some of their products as early as 1915.

Welding Holders

In the year 1924, the Western Gas Construction Company designed and erected at Lexington, Mo., their first all-welded holder. This holder was a 15,000-cubic foot, single section, water seal holder. The next holder to be of welded construction was in the year 1927 at Albion, Mich., being a 300,000-cubic foot, two section holder.

I have had reports on both holders and have within the last year inspected the holder at Albion, finding that they are in excellent condition and giving complete satisfaction.

Since that date, we have materially improved the design and have erected a total of ten all-welded holders, ranging in size from the 1000-cubic foot, single section, to the 300,000-cubic foot, two section holder.

During the period covered between the dates of the first two welded holders, general opinion was against the all-welded design and, although the engineering department was "sold" on the design, it was necessary to institute an educational campaign among prospective purchasers.

During the campaign it was decided that the transition from the riveted to the all-welded type was too great and an intermediate step or design was decided upon, i.e., that of the caulk welded type.

The Caulk Weld

In this type, the weld, as stated in the AMERICAN WELDING SOCIETY'S "Definition and Nomenclature," is a seal weld only, all joints being designed for strength dependent on the properties of the rivets and plate.

The response to this design of holder was almost unanimous in its favor; in fact, at the present time some purchasers insist upon this type above all others.

We point with pride to at least a score of holders, ranging in size from the 20,000-cubic foot, single section to the 1,000,000-cubic foot, three section holder, all of the caulk welded type. Reports have come to us at various times of complete satisfaction, and the speaker has personally inspected a number which have been in service at least three years with no evidence of leakage.

At the present time, we have completely deleted the riveted, tool caulked holder from our standards and now offer all-welded holders up to and including the 15,000-cubic foot, single section and the caulk welded type up to and including the 3,000,000 cubic feet, four section holder, as our standard line.

Similarly, in the fabrication of the pressure holder or the bullet type of high pressure tank, we have discarded, as far as possible, the riveted, tool caulked holder. All pressure holders which can be fabricated complete in the shop are preferably of the all-welded type, and those which of necessity must be erected in the field are designed as a caulk welded vessel.

I have purposely brought these two types of structures to your attention, as I am desirous of hearing and participating in a discussion on the merits and the disadvantages of the caulk welded holder and the pressure tank.

In addition to the reason stated above, we have two others for selecting this type of construction for those structures in which the size precludes the complete fabrication in the shops. First, a greater degree of tightness, and, second, a lesser amount of time in the erection and fabrication.

I have been severely criticized by some engineers for recommending this type of construction and have had various theories put to me to prove that it is entirely wrong but to date none of them have been convincing.

A number of tests have been made by the Western Gas Construction Company to prove or disprove various theories and criticisms which have been advanced but the results of the tests do not in any way agree with the theories.

Before going into the results of some of these tests I would like to impress upon you that only the plate edges are caulk welded and that the seal weld used in this type of construction is a very light fillet, varying in throat dimension from possibly $^{3}/_{16}$ in. to $^{1}/_{4}$ in.

The greatest number of criticisms of this type of joint came from those who insisted that the heat dissipated by the deposition of the weld would have an

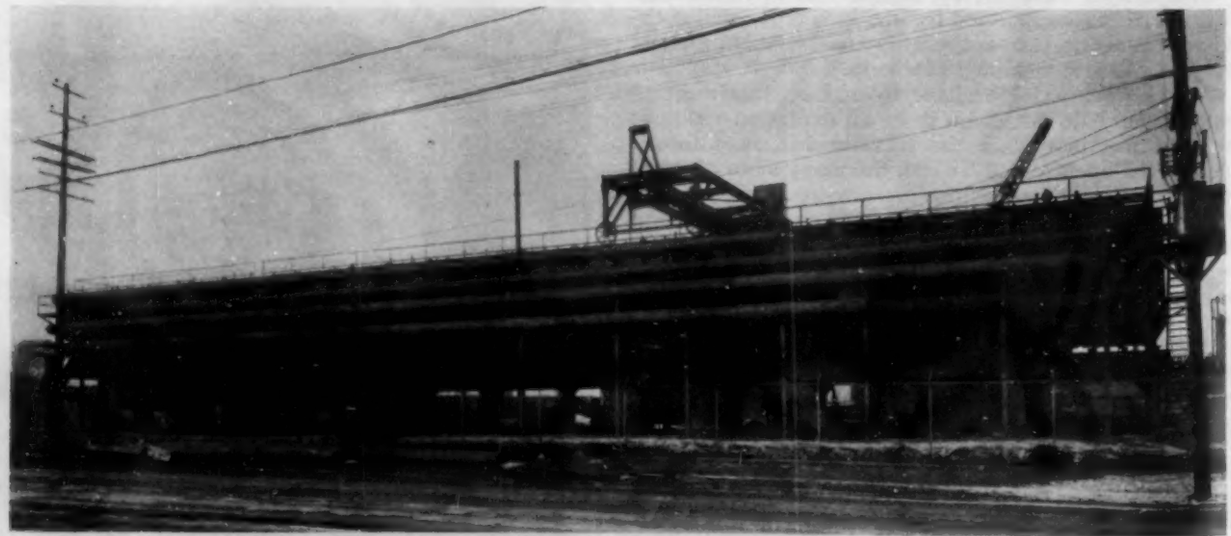


Fig. 2—An All-Welded Oxide Purifier. Designed for a Working Pressure of 5 lb. per Square Inch, Tested to 7 lb. per Square Inch. Major Portion of Material Shipped Direct to Erection Site from the Mill. Erected without the Aid of Fit-up Holes

injurious effect on the rivets, thereby reducing their holding capacity or ultimate strength.

To prove or disprove this assertion, a number of joints, all of the lap type, employing various plate thicknesses and rivet sizes, were prepared. First, a lap joint in which neither the rivet heads nor the plate edges were caulked; second, a lap joint having only the plate edges caulk welded; and, third, a lap joint in which both the rivet heads and the plate edges were caulk welded.

The results of this series of tests proved that the caulk welding of the plate edges had no injurious effect on the ultimate strength of the rivets, for in all cases the rivets in this type of joint had as great and in some cases a greater ultimate strength than the joint in which no caulking was employed. In no case did the rivets in the second type or caulk welded joint have an ultimate strength less than those of the first type.

The results of the third type or that in which the rivet heads were also caulk welded gave an ultimate strength of the rivets in which the greatest variation was 2.4% less than the first type.

To our gratification this series of tests disproved one of the contentions of our critics.

Another contention, also supported by a rather questionable theory, was that the caulk welding of the plate edges caused the rivets to turn and become loosened in their holes, thereby causing an untight seam.

To test this theory, a vessel was constructed using both tool caulked and caulk welded seams and the pressure advanced in steps of 10 inches of water column, always bringing the pressure to zero before advancing to the next higher step.

The results of this test were that leakage started in the tool caulked seams at from $1^1/_2$ to $1^3/_4$ times the working pressure while leakage on the caulk welded seams was noticeable at 2 to $2^1/_2$ times the working pressure. In the tool caulked seams leakage started at the plate edges, while in the case of the caulk welded seams the leakage was around the rivet heads. Although this did not disprove the theory advanced, at least it tended to show that the caulk welded seam held up far better than the tool caulked joint.

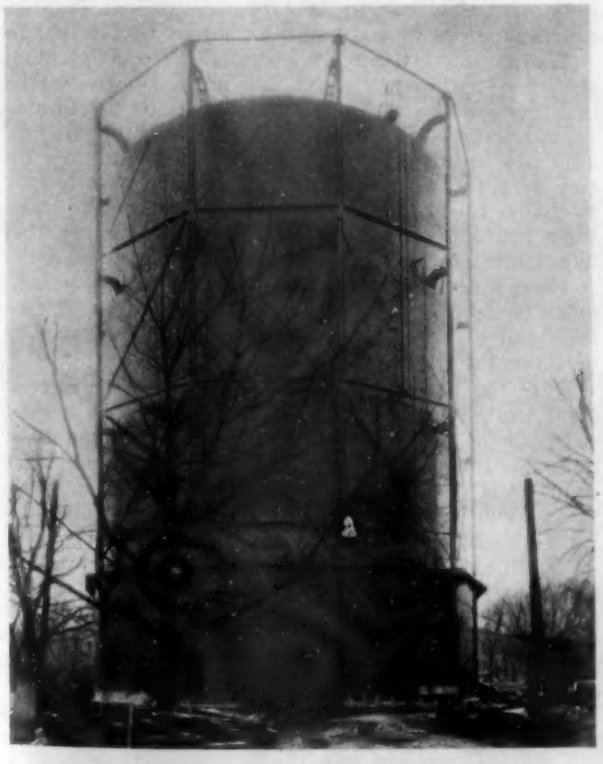


Fig. 3—All Welded 300,000 Cubic Foot, Three-Section, Water Seal Gas Holder

The speaker has made inquiries whenever possible among owners of horizontal bullet type of high pressure holders and invariably the reply has been that trouble has been experienced with the tool caulked tank, undoubtedly due to the breathing action from changes in pressure and from temperature differential.

Of the several caulk welded pressure holders which this company has designed and erected, complete satisfaction has been evidenced, which supports two recent inspections made by myself on pressure towers in service for more than a year which show no signs of leakage

Further evidence of our faith in the caulk welded joint for pressure tanks is shown in that portion of our standard specifications for the pressure "Tower," which reads as follows:

"A pressure drop leakage test shall be conducted as follows: After completion the tower is to be filled with air to one and one-half times the working pressure and allowed to stand for two (2) hours or more. The tower shall then be deflated to zero pounds gage pressure and re-inflated to one and one-half times the working pressure. After the heat of compression has dissipated a recording gage and a thermometer shall be connected and shall indicate no corrected volume loss for a period of 48 hours, from start of test. Corrected volume shall be considered as that volume of saturated air contained in the tower when corrected for gage pressure, barometric pressure and atmospheric temperature to a basis of 60°F. and 30 inches of ice-cold mercury absolute pressure. In case of failure of one or more tests, the entire procedure shall be repeated. The test shall at all times be under the supervision and subject to the approval of the Purchaser's Engineer."

It has been our experience that such a procedure is practically impossible with the tool caulked tank.

This Society, as I have been informed, has assisted the American Society of Mechanical Engineers to formulate the Fusion Welded Code for Unfired Pressure Vessels. This code contains a provision for caulk welding, which to the speaker is entirely without reason and should be revised as soon as possible.

Allow me to quote from the 1931 Edition of the "Rules for Construction of Unfired Pressure Vessels, Section VIII, A. S. M. E. Boiler Construction Code":

"U-52b. Fusion welding may be used to seal the calking edges of riveted joints and rivet heads of unfired pressure vessels, provided the plates do not exceed 0.30 per cent carbon and that the thickness of the plate or head affected by the welding is at least $^1/_8$ in. more than that required for a seamless shell of the same diameter, the same working pressure and the same grade of material. Such seal welding shall not be applied until after the vessel is made tight as evidenced by the regular hydrostatic pressure test prescribed in Par. U-64. Seal welding may be used on nozzles and their reinforcing plates under the same conditions On unstayed dished heads, seal welding shall not be applied closer than $^1/_2$ in. to the point of tangency of the knuckle of the flange. Seal welding may be applied only when the weld metal is deposited in a single layer having a throat thickness of not less than $^3/_{16}$ in. nor more than $^5/_{16}$ in. The heat from welding shall not distort the plates or

loosen the rivets in such a manner as to break the initial bond affected in the riveted joint. After seal welding, the vessel shall be resubjected to the prescribed hydrostatic test."

This specification in my opinion is a step against the use of the seal weld or caulk welding. As explained in a letter received from Mr. C. W. Obert, Chairman of the Welding Conference Committee on Welding with the Boiler Code Committee, this stipulation "involves the treatment of the result of the seal weld as a groove cut into the plate underneath as far as the weld extends, and provides for a penalization of the plate by requiring a sufficient increase in its thickness to offset the heat penetration of the seal weld."

Our answer is that we feel that this is a sad admission on the part of the AMERICAN WELDING SOCIETY to make, because in effect it is an admission that welding brings about a condition which makes it dangerous to use. If the Welding Society is ready to admit that the strength of the deposited metal is not as good as the parent metal, it seems to us that they should carry this deduction to a further conclusion and admit that a butt weld is of absolutely no value since a butt weld is made entirely of deposited metal. Incidentally, on all of the numerous tests we have made, we have yet to encounter one condition where the plate broke at the point of caulk welding.

Mr. Obert attempted to show that in most cases this clause is not a penalization against caulk welding by taking a small diameter vessel, using a low efficiency joint and comparing the shell thickness necessary against that required by code, showing that the first vessel required a heavier plate.

We are not interested in the small vessels, these we fabricate entirely by arc welding. What we are interested in are those whose size precludes fabrication in the shop, and utilizing a high joint efficiency.

Let me illustrate. A pressure tower, recently designed and erected by us, has a

Diameter of 39'0"
Working pressure of 45 lb. per square inch
Unit stress of 11,000 lb. per square inch
A joint efficiency of 95.4%.

Then, the thickness of shell plate required is

$$t = \frac{45 \times 39 \times 12}{2 \times 11{,}000 \times 0.954} = 1.0035'' \text{ or } 1\,1/64''.$$

If designed according to code, the shell plate must be

$$t = \frac{45 \times 39 \times 12}{2 \times 11{,}000 \times 1.00} + \frac{1''}{8} = 0.9573'' + 0.125 = 1.0823 \text{ or } 1\,3/32'',$$

or an increase of $5/64''$ in the thickness of plate necessary.

Another case is as follows:

Diameter of 34'0"
Working pressure of 60 lb. per sq. in.
Unit stress of 11,000 lb. per sq. in.
A joint efficiency of 95.4%

giving:

$$t = \frac{60 \times 34 \times 12}{2 \times 11{,}000 \times 0.954} = 1.1664'' \text{ or } 1\,11/64''$$

taking the code recommendations:

$$= \frac{60 \times 34 \times 12}{2 \times 11{,}000 \times 1.00} + \frac{1''}{8} = 1.1127 + 0.125 = 1.2377'' \text{ or } 1\,1/4''$$

or an increase of $5/64''$ in the thickness of plate necessary.

Why should the caulk welding be penalized $5/64''$ or a percentage of 7.7%?

Again, any person familiar with the welding arc should realize the utter lack of necessity of tool caulking to tightness, testing and then caulk welding. Here, once more, a penalty is placed on the seal weld.

As soon as the arc is struck the tool caulking is useless, being burned away. Why the necessity of the preliminary tool caulking and test? Perhaps we should assemble the structure with fit-up bolts and caulk, then test and then drive the rivets; to the speaker the logic is as practical as the procedure given in this specification.

After all, the proof of the pudding in this case is the performance in actual service of which the Western Gas Construction Company has many structures to support its contentions.

Other Welded Products

Relative to the design and fabrication of other products of the company. Since the year 1927, our purifiers or oxide boxes have been of the all-welded construction. Possibly, the design and construction of our present type of purifiers is the most successful of all. As with the welded holders and storage tanks, erection is accomplished entirely without fit-up holes. All plates and structural shapes are shipped directly to the erection site from the mills—thus leaving room in, and more time for, the shops in the fabrication of those structures of a size which can be completely fabricated in the shops.

The plate and structural shapes of the liquor flushing tanks are also shipped direct from the mill.

Dehydration towers, condensers, coolers, in fact all structures, especially those of the cylindrical shell type, if precluded by their length to complete fabrication in the shop, are welded in sections with either riveted caulk welded or flanged and bolted field joints. If of a size that can be handled in the shops and on the railroad cars, they are of the welded type.

Bare Versus Covered Electrodes

On different occasions I have been requested to give my experience in the transition from the use of the bare wire electrode to that of the covered electrode, also any ideas or suggestions relative to this change.

To my mind there are possibly three different obstacles to surmount. First, the inertia of the welding organization as a whole. Let me elaborate a bit further on this score. Your organization as a whole has probably developed a given procedure, technique and routine with the bare wire, and for any one person to try to change the familiar routine on short notice and plunge them into a confused state with a strange and entirely unfamiliar procedure is akin to the person who tries to rouse a desperately tired and sleeping child, who has fallen to sleep in a chair and send him to bed. It takes time and a great amount of perseverance on the part of those instigating the change.

Next the average welder is content to let so-called good work remain as is. He is putting out a good, strong weld using the bare wire—why change to an unknown rod which is more difficult to manipulate and change his entire technique, under possibly more adverse conditions? Do not for one instance think that I am criticizing the welders, as a class, for having a lack of ambition, because such is not the case. What I am trying to impress upon you is that it is human nature to let well enough alone, therefore we must seek some measure of convincing the welders that we are trying to help them improve their work and also broaden their field.

Again, there is in the shops, where entire fabrication is not accomplished by welding, a certain coterie who are not weld-minded and who, to my way of thinking dread the inroads into their trade or jobs, which weld-

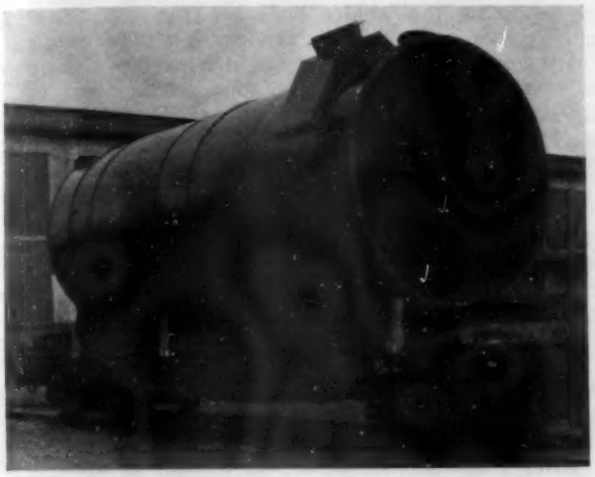


Fig. 4—All-Welded Four-Pass 10'0" Diameter by 27'8-1/4" Water Tube Condenser

ing is certain to make, and yet who have not the energy or ambition to accept welding as an aid rather than an enemy, therefore they are continually "knocking" welding as a whole.

As an illustration of this latter class, some time ago the engineering department had completed a new welded design of the saddles for a horizontal pressure holder and it had taken the place of the original riveted construction on a project which was being fabricated in the shops. While making one of my frequent visits to the tank shops, one of the men rushed up to me and in a rather excited voice asked if I had seen the drawings for the saddles. I simply laughed, since it happened that the design was the work of one other man and myself. He took hold of my arm and led me over to where the completed saddles stood. Shaking his head dubiously, he insisted that the design should be rechecked as he was positive that they would never stand under the proposed loading.

A few minutes later I happened to meet the welding foreman, who greeted me with a smile and his first words were, "Have you seen the new saddles for Braintree? Say, they'll hold up all Hell and high-water."

Of this class, my idea is that the only salvation is education in the characteristics and properties of welding and if the light cannot be brought to them, it is better to go along without them.

In our particular case the mistake was made, you might say, of trying to force a new method and a new electrode upon the shops. Although we were positive that the bare wire welding produced in our shops was the equal of any other and in a great many cases, better than others, we did not fail to realize that the bare wire welding as produced would never take the place of riveted construction due to its many shortcomings. Therefore the engineering department selected the covered electrode, which at the time appeared to be the best and it was given to the shops as the rod to be used in the future, if after experimentation it proved to have the characteristics and properties assigned to it by the manufacturer.

A demonstrator of the manufacturing firm visited the shops and proceeded to demonstrate the technique of the covered rod. Immediately the welders seemed to unite to disparage the new electrode.

Complaints were made to the speaker that the new rod produced such a glare that workmen in the vicinity of the welder were blinded; the additional heat caused injury to the welders; the fumes given off were injurious to the eyes, lungs and stomach of persons in the shop; the appearance of the weld was (as the operators explained) "sloppy"; the rod under-cut; too much time had to be spent after deposition in cleaning the parent metal and removing the slag; all of the welders were positive that the (as they thought) extreme heat necessary to weld with the new electrode was injurious to the parent metal.

I could seemingly go on and on with a list of innumerable faults claimed by the operators, and when the first coupons were tested and the fractured welds inspected, the results were discouraging, to say the least.

It was finally decided that a new way of handling the situation must be evolved, that we had blundered in trying to give the welders a new electrode and that they must give us the new rod. It was a psychological reason more than anything that was working against the acceptance of the electrode; what the welders wanted was a rod of their own and not one forced upon them.

Following the new course of reasoning, the welding foreman and one welder, who was acknowledged to be the best in the organization, one who took an unusual amount of pride in his work and who seemed to devote some time to studying welding, were called together and after a talk on the general subject of welding, they were asked to weld coupons employing the bare wire and these samples were then fractured to show any evidences of porosity, gas pockets, slag inclusions, etc. They were shown etched samples under the microscope and the undesirable elements present in the bare wire deposition. Rough tests were also made to show the cast characteristics of the bare rod, its lack of resistance to shock or impact, heat treatment and corrosion.

After these tests the samples of the demonstrator were put through the same routine, and the differences pointed out.

The change in attitude of these two men was remarkable, due, I think, to the fact that their pride in their own work had been touched. The two men were then placed in the hands of the demonstrator and had soon acquired a working knowledge of the technique of the new electrode. As soon as they were satisfied that their work was passable, tests were made on their welds.

As soon as the two men were handling the coated electrode and producing welds which met with our specifications, the next two best welders were turned over to them for instruction, and so on until the entire organization had become fully familiar with the handling of the covered electrode.

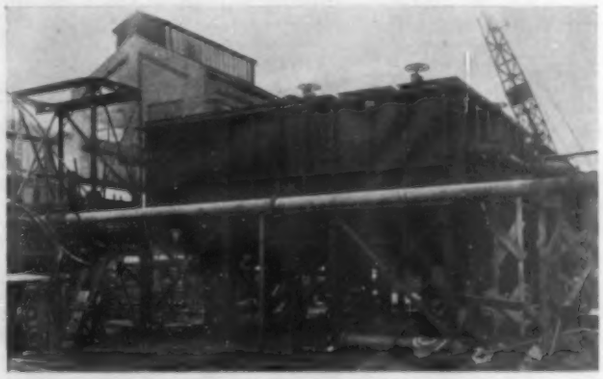


Fig. 5—All-Welded Decanter Tanks—Material Fabricated Almost Entirely at the Erection Site

In the meantime, whenever possible the first two were given production work, using the new rod, tests being made on their work in their presence.

Soon the entire attitude of the organization had changed, it was now their rod and none other was quite as good. Remarks could be heard frequently about their coated rod and about what they could accomplish with it.

In assigning production work it was surprising how soon the operators would always ask, "Are we to use our new rod?"

Before the year was passed the bare wire electrode was a memory and the operators were truly disappointed whenever the bare electrode was called for on any work assigned to them.

From the above experience and also that gained from assisting two smaller shops to change to the use of the coated electrodes, I would suggest that the most plausible way and that easiest to accomplish would be to enlist the aid of one or possibly a number, if the organization is large enough, of your best welders. Explain to them the cause for wishing to change, point out to them the advantages which will be to their benefit, as well as the company's because of the increased quality of their work and the broadening of their field and there is no doubt in my mind that they will respond. Let the new electrode be their rod, something to take pride in, something that will increase their efficiency, quality of work and make possible a greater amount of work for them, as there is no doubt that fabrication by welding can be employed on structures, using the coated electrode, that it would be suicidal to construct with the bare wire.

To my mind there are four features which the covered rod possesses that make it the superior instrument in welding, i.e., a higher tensile strength, greater ductility, greater resistance to corrosion and greater speed of deposition, all of which influence the cost of production.

I have been told by some discouraged shop men, who are just commencing to employ the coated electrode, that they are not obtaining an increase in speed. As an engineer, my reaction to this problem is that of the four mentioned desirable features, increased speed is the least desirable. We are principally interested in obtaining a product, the quality of which is of the best and there is no question that the coated electrode or the shielded arc wire, when properly handled, gives a structure far superior to any which has been fabricated to date, and as to cost, if the three other features are obtained, there is no doubt that on a fair basis of comparison the fabrication with the covered rod gives a lesser cost than the bare wire.

Speed of deposition and naturally increased reduction in the cost of fabrication will eventually be forthcoming as your acquaintance and familiarity with the technique grows.

Tests

Probably some of those present will be interested in the tests used in our plant, both for qualification and inspection of an operator's welds and for determining the characteristics of a new electrode which has been brought to our attention, for, may I add, we are continually on the outlook for any new and improved rod or method of welding.

If a new rod is being investigated, the welder is turned over to the manufacturer's demonstrator and allowed ample time to familiarize himself with the technique and characteristics of the electrode; then the procedure of preparation of coupons and testing is the same for all. In some cases no demonstrator is available and in that case the welder does his own experimenting until convinced that he is producing a good weld.

By way of explanation, it might be well at this point, to state that the majority of our products are fabricated from two classes of steel, i.e., Grade "A" tank steel and flange steel; naturally the welding characteristics of these two grades of steel vary.

The tests for tank steel are as follows: A plate, 12 feet in length and generally ranging from $^1/_4$" to $^5/_8$" in thickness, is rolled to a radius of from 12" to 15", and then welded to form a cylindrical shell, 12′ in length and 24" to 30" inside diameter, records being made of the current characteristics, time of deposition and rod consumption, and any other points or items of interest.

We use the cylindrical shape in making our test welds, as the simplest way of duplicating actual working conditions, bearing in mind "locked-up" stresses or residual strains.

After the weld has cooled and same cleaned of all slag and a visual inspection made, special attention being paid to under-cutting and the appearance of the completed weld particularly wherever the arc has been broken, the kerosene test for porosity is made.

A length of 2′ is then cut from one end of the cylinder and the remaining length of shell (10′) is made into a tank by welding a flat, reinforced head in both ends.

We now have samples of the operator's butt-weld and fillet welds.

The completed vessel is then given a hydrostatic test, advancing the pressure by steps of 50 or 100 lb. per sq. in. up to 1000 lb. per square inch, but always dropping back to zero pounds pressure before advancing to the next higher step and giving the customary hammer test at the completion of each step.

Provided no defects have evidenced themselves during this test, we have developed the policy of lifting the tank to a height of approximately 25′ and allowing it to drop several times on twelve by twelve timbers, so that it is deeply indented across the welded longitudinal seam. Pressure is again applied and results noted. I might add that on only one occasion has the vessel failed to resume its original cylindrical shape with no fracture of the weld; in some cases the indenture has been from 4" to 5" deep and covering an area of approximately four square feet.

From the two-foot section previously cut from one end of the shell, standard tensile and parent metal coupons are taken and sent to the laboratory for tests.

Additional coupons are taken for making rough tests, as follows: Coupons with the weld running transverse to the length at the mid-point are cold worked under the pneumatic hammer until the middle portion of approximately half the entire length of the coupons is one-half or less the original width and of original thickness.

Another coupon of the same characteristics is heated to a forging heat and twisted while hot at the center through at least three complete turns.

Corrosion tests are also made in sulphuric and hydrochloric acid solutions and alternate immersion and drying in salt or rainwater.

A bead is also laid on a $^3/_8$" × 3" bar stock and after draw filing the surface of the weld bead to a smooth finish, lines are scribed $^3/_4$" apart and the coupons placed under the press and bent in such a manner as to put a tensile load on the weld bead.

Provided the test is to be made employing flange steel, we invariably follow the tests prescribed by the American Society of Mechanical Engineers' code for the fusion welding of unfired pressure vessels.

Welding of Pipe

By S. LEWIS LAND

†Mr. Land is Educational Director of the Heating and Piping Contractors National Association.

Welding and the Welder

THERE seems to exist some misconceptions concerning the status of the welder and the place of welding not only as they affect the steam-fitting trade but the other building trades as well.

With the increasing development of the welding industry as an important factor in the various building trades, it has become generally recognized from the standpoint of labor, the employer, as well as the consuming public that the welding process must not only be accepted but promoted to its fullest possible utilization.

During the period of the early development of welding an international welders' union was launched and application made for membership in the American Federation of Labor which was rejected. The American Federation of Labor as well as its various affiliated national and international trade unions recognize that welding is a process and that the welder's torch is simply a new tool to be added to the kit of every mechanic in the various trades in which welding is being employed.

The entire matter, from the standpoint of labor, was summarized briefly in an important decision rendered by the American Federation of Labor at the time of its 1916 convention as follows:

"We recommend that this convention declare that 'acetylene welding' is a process, and that 'acetylene welder' is a tool, which can no more come under the exclusive jurisdiction of any one trade or calling than can the hammer or the saw."

The same decision was reaffirmed by the 1919 convention of the American Federation of Labor. In a decision rendered April 28, 1920, in the matter of a dispute between tradesmen in various trades concerning the jurisdiction over welding, the following agreement was concurred in:

"Representatives of the Electrical Workers, Sheet Metal Workers, Iron Workers, Plumbers, Steam Fitters and Machinists mutually agreed to the following decision:

"'Each trade to have jurisdiction over all acetylene and electric welding when such process is used to perform the work of their respective trades.'"

The employer in the early stages of the development of welding was forced to employ welding specialists aside from his regular mechanics. With the rapid growth of welding and its increasing utilization and a more general opportunity for tradesmen to learn the process, there came a recognition on the part of the employer that at least a certain percentage of his mechanics, particularly those employed all year around, must be able to do welding.

Throughout this development there has been some confusion among vocational school administrators concerning the objectives and procedures to employ in meeting the need created by the introduction of welding in the various trades. There is coming to be a general recognition on the part of the school administrator of the necessity of differentiating between groups in setting up training programs for various trades in welding. With these more recent developments we find now in many places special classes in welding for each of the trades in which the process is employed.

Tentative Layout of Units for Course in Pipe Welding

The following outline for a course in pipe welding is tentative and subject to change. It is submitted here with the request that you let us have your suggestions for changes or additions which we can incorporate in the revised and completed course outline.

Unit No. 1.	Knowledge of the development, application, and process of pipe welding and cutting.
Unit No. 2.	Knowledge of the various items of apparatus and equipment and their uses.
Unit No. 3.	Knowledge of the various items of welding materials and supplies.
Unit No. 4.	Knowledge of precautions and safe practices.
Unit No. 5.	Knowledge of and ability to assemble and adjust apparatus (2 job sheets—one on setting up welding and cutting units; and one on adjustment of pressures and flame).
Unit No. 6.	Practice cutting and welding on steel plate.
Unit No. 7.	Cutting pipe. Ability to cut 2″ and 4″ steel pipe.
Unit No. 8.	Cutting bevel on pipe. Ability to cut bevel on 2″ and 4″ steel pipe.
Unit No. 9.	Making a rotating pipe weld in horizontal position. Ability to cut, bevel and weld 2″, 4″ and 6″ pipe.
Unit No. 10.	Knowledge of the use of templets.
Unit No. 11.	Cutting branch openings. Ability to cut branch openings for the following: 2″ branch intersection into 4″ main at 90 degrees (Tee). 4″ branch intersection into 6″ main at 90 degrees (Tee).
Unit No. 12.	Welding branch connections. 2″ branch intersection into 4″ main at 90 degrees (Tee). 2″ branch intersection into 4″ main at 45 degrees (Y). 4″ branch intersection into 6″ main at 90 degrees (Tee). 4″ branch intersection into 6″ main at 45 degrees (Y). 6″ branch intersection into 6″ main at 90 degrees (Tee). 6″ branch intersection into 6″ main at 45 degrees (Y).
Unit No. 13.	Making a position weld in horizontal pipe. Ability to cut, bevel and weld 2″, 4″ and 6″ pipe.
Unit No. 14.	Making a weld in vertical pipe. Ability to cut, bevel and weld 2″, 4″ and 6″ pipe.
Unit No. 15.	Overhead welding. Ability to cut and weld overhead a 2″ nipple on a 4″ pipe. Ability to cut and weld overhead a 4″ nipple on a 6″ pipe. Ability to cut and weld overhead a 2″ nipple at an acute angle on a 4″ pipe.
Unit No. 16.	Ability to cut and weld pipe headers.

NOTE: The first five units are presented as group instruction at the opening of the course and thereafter as individual instruction as occasion requires. Units 6 to 16 are given as individual instruction. No student should be permitted to advance from one unit to another until he has proven to the satisfaction of the instructor that he has acquired the ability to do the particular job.

Gas Welded and Brazed Joints for High Nickel Alloys

By F. G. FLOCKE, J. G. SCHOENER *and* R. J. MCKAY

†Paper read before the 32nd Annual Convention—International Acetylene Association, Chicago, Illinois—November 11, 12, 13, 1931, by F. G. Flocke, J. G. Schoener, of the Development and Research Dept., International Nickel Co., New York, and R. J. McKay, Supt. of Technical Service, The International Nickel Co., New York.

Summary

THIS paper discusses the practical features of and certain of the pitfalls encountered in the oxyacetylene welding of Monel metal, pure nickel and Inco chrome nickel in chemical fields. Where fluxes and welding rod are used, they should be right in composition. Proper jigging and clamping is essential, particularly with the lighter gages. Some methods of making typical seams by welding, silver soldering and brazing are described.

* * * *

The three alloys considered here are Monel metal, pure nickel and Inco chrome nickel. The first two are the most commonly known and widely used of the high nickel alloys, while the last is a recently developed metal having a superior resistance to tarnish or stain and somewhat higher physical properties than pure nickel.

Each of the three alloys has a definite place in the chemical industry and each is used in a wide variety of conditions.

Monel metal is resistant to both acid and alkaline corrosion, as, for instance, in salt dryers, dye tanks, stills, retorts and condensers, extractor baskets in ammonium sulphate manufacture, drying trays in manufacture of dyestuffs and pharmaceuticals, rubber latex spraying equipment and innumerable pieces of chemical engineering equipment. Also, laundry machinery and dry cleaning equipment, meat packing viscera and abbatoir equipment such as oleo melting kettles.

Nickel, while slightly less resistant to acids is very resistant to alkalis and to a wide range of salts. The most important application of nickel lies in caustic and food product evaporators in which the tube sheets, tubes and downtakes are of pure nickel with the body of nickel clad steel. One such caustic job recently employed upward of 200,000 lb. of rolled nickel while the average job employs in the neighborhood of 20,000–30,000 lb. Pure nickel also finds application in the ammonia oxidation process in the manufacture of viscose and cellophane and in manufacture of safety X-ray film and photo emulsions. Steam jacketed kettles of nickel are a standard item for the food industry as are pure nickel brine and syrup tanks.

Inco chrome nickel is particularly useful in handling foods and milk products because of its high surface resistance which parallels that of the stainless steels rather than nickel or Monel metal. General statements as to its applications would, on account of its newness, be mere estimates, but it is expected that it will fill certain specific requirements in the chemical industry.

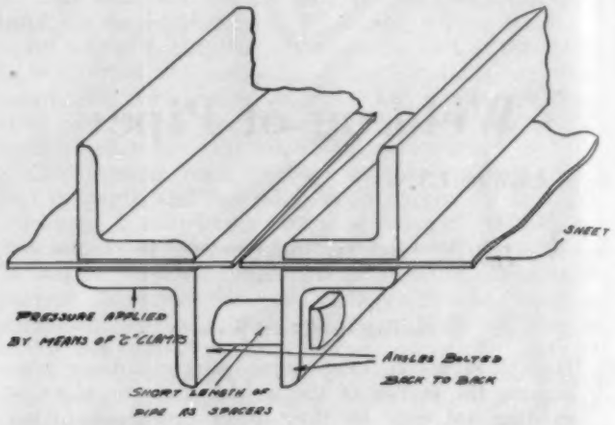


Fig. 1—Jig of Angles for Making Butt Seam on Sheet

For the making of all this equipment there is available such mill products as sheet, plate, strip, seamless pipe and tubing rods, wire, flats and angles. The company which the writers represent produces in its refineries and rolling mills, mill products only and does not build fabricated equipment. The present discussion covers experience gained in service work in connection with outside fabricators.

The oxyacetylene welding of nickel and Monel metal has been practiced for more than a decade quite satisfactorily. It has been and is being used successfully in the fabrication of all types of equipment in the chemical field as well as in many applications far afield of the chemical industry. Improvements in recent years, both in fluxes and welding rod, have aided in the advancement in the welding of high nickel alloys.

Welding is of fundamental importance in the building of corrosion resistant equipment. Former papers have discussed certain metallurgical features of welding and have included incomplete notes on successful field practice of some years ago. However, welding in general has made valuable strides during the last three or four years, during which time there has been a parallel betterment in welding practice on nickel alloys. Very little, so far as high nickel alloys go, has been written or published covering these more recent practices. It is the purpose of this paper, therefore, to cover the practical side of the oxyacetylene welding of Monel metal, pure nickel and Inco chrome nickel, consolidating the old practices and newer developments.

There are three essentials necessary to the satisfactory

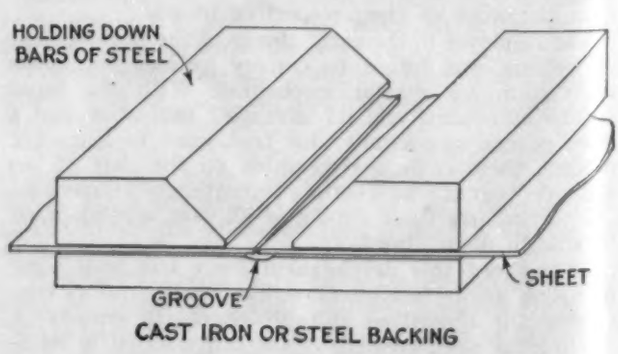


Fig. 2—Variation of Fig. 1 for Butt Seams

completion of a job: 1. Correct materials and with that we include correct welding rod, flux and material being welded; 2. Proper setting up of job which includes jigging so as to hold work in place during welding; 3. Proper procedure.

General

In the main, the oxyacetylene welding of the three high nickel alloys is much the same, with only minor variations. These are all strong alloys, rather stronger than common steels as indicated together with other physical and mechanical properties in the table below.

Comparative Physical Properties

Tensile Properties

Sheet Metal Annealed

	Tensile Strength	Yield Point	Elong.	Reduction in Area	Rockwell B Hardness
Monel Metal	65–75,000	25–35,000	35–50	65–75	68
Nickel	65–75,000	20–30,000	43–43	65–75	65
Inco Chrome Nickel	90,000	40,000	40	...	77
		Cold Drawn Rod—Normalized			
Monel Metal	90–110,000	60–80,000	20–30	35–50	90–100
Nickel	80–95,000	70–80,000	25–35	40–60	90–100
Inco Chrome Nickel	115,000	95,000	25	65	95
		Cold Rolled Sheet—Full Hard			
					Shore
Monel Metal	100–120,000	90–110,000	2–8		95–100
Nickel	95–110,000	90–100,000	2–8		35– 40
Inco Chrome Nickel	150,000	125,000	1.5		48

Physical Constants

	Density	Heat Expansion	Heat Conductivity	Modulus of Elasticity
Monel Metal	8.80	0.000014	6.6	26,000,000
Nickel	8.85	0.000013	15.5	30,000,000
Inco Chrome Nickel	8.52	0.000013	3.25	31,000,000

There is a peculiarity manifested in high nickel alloys that is perhaps not nearly so marked in other metals though present—a hot short range—a range of low tensile strength and brittleness, between the temperatures of 1450–1650° F. Both above and below this hot short range they regain their normal strength and ductility. For this reason expansion and contraction must be taken into account, to see that there are no undue stresses set up or existent while the weld metal and immediately adjacent metal are passing through that hot short range as the weld is cooling. This is accomplished in part by allowing the weld metal to draw and contract in a natural manner instead of holding it so rigidly as to prevent contraction.

Clamping

It is in part because of the condition mentioned above, as well as the fact that it facilitates welding to a marked degree, that proper jigging is found essential not only in non-ferrous alloys of high melting point, but for the ferrous group too. It is the partial or complete overlooking of this question of jigging that is at the root of quite a number of welding difficulties. This holds particularly for sheet work rather than for heavy plate, because the tendency of the former to warp is far more pronounced. When speaking of jigging we have in mind the holding in place and holding in line the edges being welded by means of a skeleton frame to prevent distortion. Take as an example a 2 ft. or 3 ft. longitudinal seam on the side of a cylindrical tank 2 ft. in diameter of a medium gage metal. There is a tendency in speeding up the work for the welder to tack at one end then spread and clamp the other. As he progresses in the welding, there is bound to be some distortion, one edge of the seam lifting up, or in approaching the end the edges may have drawn together too fast and so overlap.

It is better practice to take enough time to prepare the work properly. The appropriate jig is simple, consisting of a piece of $^{3}/_{16}$ in. steel plate, 8 in. to 10 in. wide and as long as the seam with a shallow lengthwise central groove, two angles, one for each top side of the seam and four C-clamps. The principles involved are illustrated later in the paper.

There may be some question why more care is to be taken in these cases than is the practice in jigging steel. As an analogy we might consider the expense which is justified in caring for a fine watch as compared with a common alarm clock, simply on a basis of value. In working high nickel alloys, a greater risk of loss is involved than is the case with steel. The authors ask your pardon in dwelling on this simple point, but would emphasize on the basis of much experience, the economic value of thorough jigging and clamping.

Figures 1, 2, 3 and 4 show a few of the jigs used in making various types of seams, illustrating in principle what is generally used. All are simply made. C-clamps

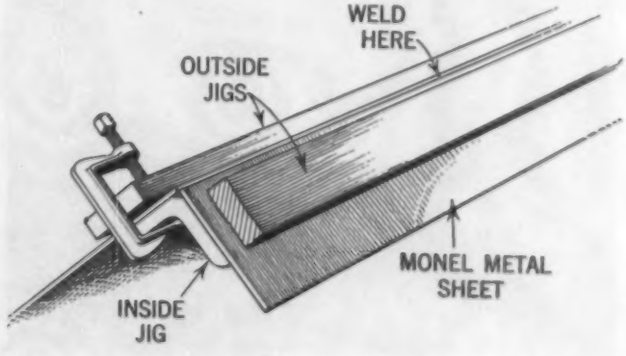


Fig. 3—Jig for Corner Weld. Note the Sharp Corner of Angle Is Removed, and That Inside Corners of Sheet Are Just Touching

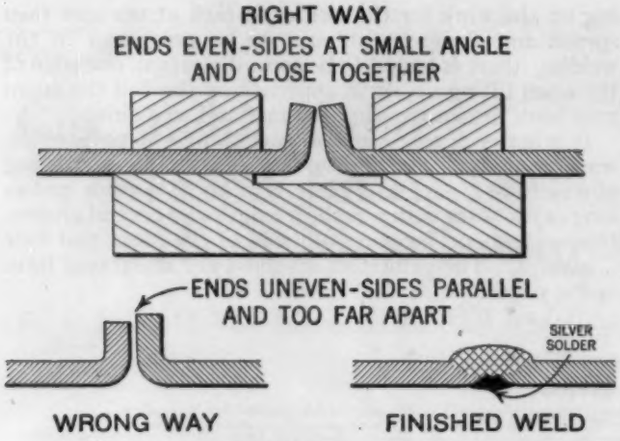


Fig. 4—Jig Used for Edge Weld. Angles Are Sometimes Substituted for Top Rectangular Bars

are used for holding the jig together when in use, so as to get metal-to-metal contact between jig and sheet. By doing this, the jig acts as a chill, also absorbing heat that would otherwise work into the sheet and warp it. Occasionally copper bars have been used to have a maximum heat absorption, and where a minimum of buckling is desired. A groove is shown in the lower section, the purpose of this being to permit more rapid welding, as well as to allow the bottom edges to be thoroughly fused. On the corner weld, the sharp corner of the inside jig angle is filed away slightly for the same reason.

In all the cases above, the flux is generally applied by painting the thin paste on both sides of the seam, top and bottom.

Flame

The oxyacetylene flame used should be very slightly reducing, that is, a little excess acetylene, with only a slight feather, no longer than an eighth of an inch, showing beyond the tip of the luminous cone. In an oxidizing flame copper oxide (Cu_2O) forms, in the case of Monel metal, and dissolves in the molten metal rendering the alloy brittle and less resistant to corrosion. In the case of nickel and chrome nickel we get a definitely oxidized metal if a reducing flame is not used. We would prefer to recommend a neutral flame, but it is seldom that a set of gages handled by the average welder will give an absolutely true neutral flame after a short period of use. There is usually some waver, either toward the oxidizing or to reducing side, therefore, as a matter of safety a slightly reducing flame is recommended.

It is well, during actual welding, always to keep the end of the welding rod well within the flame, so as to prevent the oxidation that would result if the hot rod were brought outside of the protecting flame envelope into the open air. Besides being reducing, the flame should be soft, rather than harsh, as is the case when too small a tip is used.

Fig. 5—Completed 3000-Gallon Tank of 0.109 Nickel. Acetylene Welded Entirely

Fluxes

A flux is always used for Monel metal and Inco chrome nickel, and occasionally with pure nickel. Inco Gas Welding and Brazing Flux is used with Monel metal and nickel, while a special flux is available for chrome nickel. These fluxes were developed for the three high nickel alloys under discussion, and are not to be considered as applicable for other metals.

In using flux, we have a twofold purpose in mind, namely, (1) to protect the metal from oxidation and to dissolve oxide, (2) to improve the fluidity of the molten metal. Flux may be used either as a dry powder into which the heated end of the rod is dipped, or as a thin paste. The paste is made by mixing the dry powder with alcohol or dissolving it slowly in boiling water. To secure proper solution, the water must be boiling and not simply hot.

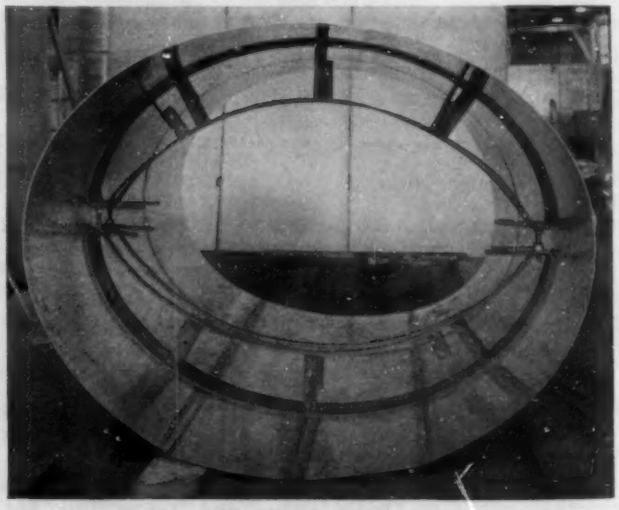


Fig. 6—Skeleton Jig Used for Girth Seam. Note Jacks for Spreading Sections

When used dry, the flux will flow around each drop of metal and penetrate to the underside of the weld, thus protecting the weld metal from oxidation and actually keeping the metal bright. With reasonably careful handling, this practice fuses the metal completely through the sheet producing a shallow reinforcing bead on the under surface of the seam. When used in paste form the flux is painted on the seam with a small brush or acid swab, and occasionally on the welding rod.

Ordinary borax is widely used as a flux and due to its valuable properties has often been advocated as a welding flux for high nickel alloys. As a matter of fact, it is one of the ingredients of the Inco flux but is present in relatively minor proportions, and we do not consider it a suitable flux in itself. Borax improves fluidity of the molten metal, but when present in large proportions the extra fluidity is accompanied by lack of ductility in the finished weld. It does not dissolve the metallic

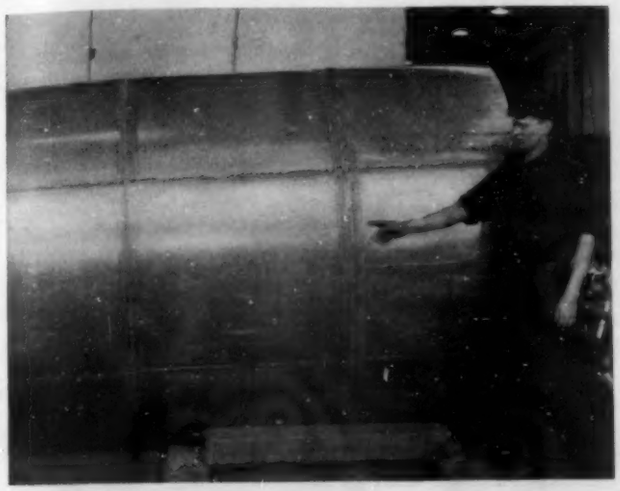


Fig. 7—View Showing Set-Up for Welding Girth Seam from Outside. Note Spacing of Tacks

oxides sufficiently to produce the clean appearance sometimes necessary and it is rather difficult to remove. The recommended flux is free from these defects.

The Inco Gas Welding and Brazing Flux is used for several related purposes: gas welding of Monel metal and nickel, though it is not necessary for nickel except to improve the flow; for silver soldering, here to make solder flow freely and dissolve oxide; for brazing with ordinary yellow brazing rods and the white bronze described later. With all the above uses it can be applied in either dry or paste form, though with silver solder, paste is preferred.

This flux does not corrode the high nickel alloys and need not be removed on this account. However, it is usual procedure to remove it as a matter of cleanliness and this is easily done by dissolving in warm water.

Manipulation and Fusion

In introducing a steel welder to the welding of nickel alloys it is often found that he puddles (boils) the metal excessively. For the best results on high nickel alloys there should be little puddling; the molten pool should be kept quiet with the tip of the luminous flame just touching its surface. Puddling burns out the deoxidizers which are important ingredients of these alloys although present in very small amounts. These deoxidizers are sufficient to insure good physical properties and are present in sufficient excess in the welding rods. However, if the welder puddles and boils the metal excessively he will "take the life out of it" by removing the deoxidizers and obtain a brittle and gassy weld.

Extra caution should be exercised in this respect with nickel alloys, because nickel absorbs gases quite readily while molten and precipitates them as gas pockets on solidifying.

The proper size of tip is best determined by the welder's judgment. If the welding progresses too slowly, it is logical that he should increase his heat, either by a larger flame with the tip already in the torch, or by putting in the next size larger tip. And conversely, if he is hurried, and as a result burns holes in the metal, and the weld metal is boiling instead of being quiet, obviously the heat should be reduced. It is difficult to say with any degree of certainty just what tip size to recommend for a particular gage metal, because of the various factors entering, though as basic practice the same size or one size larger than that recommended by the torch manufacturers for similar gage steel may be used.

Welding Rod

Welding rods are in general of the same composition as the alloy being welded. This is necessary as comparable corrosion resistance with lack of galvanic effects is almost universally desired. Some leeway is possible with the deoxidizing additions and the manufacturers of nickel undertake to furnish proper welding rods where these are specified. Wire should be bright annealed, soft and free from oxide. Not every wire, even though of normal composition for the alloy in question, will give satisfactory results. Rod to be used for welding should always be so specified.

Concrete Applications

A few actual conditions encountered in welding are grouped below according to the type of seam, with examples of jobs and procedure followed.

Perhaps the most common is the butt seam, used for medium and heavy gage metal. The setting up is important, more particularly in the lighter gages.

As a concrete example we will take a 3000-gallon tank of 0.109 nickel built as a truck tank. The tank proper is shown in Fig. 5. Note the longitudinal seams in Fig. 7. Two seams were made by welding across the 40-in. width of the sheet, welding from both sides, using a setup similar to that shown in Fig. 1. You will note it is not elaborate, being merely a skeleton made of steel angles to hold the edges in line. One 40-in. seam having been welded, the length was rolled into a cylinder, and then the second 40-in. weld was completed to make a continuous cylinder. Each of the 5 sections were made in this way.

In joining two such sections by a girth seam a jig as shown in Figs. 6 and 7 was used. This again was only a skeleton made of steel flats and angles, constructed in sections so they could be spread by small threaded jacks. The entire seam was tacked $^5/_8$ in. apart as seen in Fig. 7, having an even space between the edges of the sheets all the way round about $^3/_{32}$ in. wide. By welding from the inside first, it was easier to control the height of the bead, and so add a minimum of excess metal and thus less grinding and less dressing down on the inside. In the same setup, and without removing the jig, the outside of the seam was welded, first lightly grinding off the oxide.

Another job just recently completed was the welding together on a girth seam a special nickel casting and a cylinder of rolled nickel, both 16 in. diameter and $^3/_8$ in. wall. These two pieces were beveled from the outside with a total vee of 90°, then tacked in 5 places so that after tacking there was an even space of about $^3/_{32}$ in.–

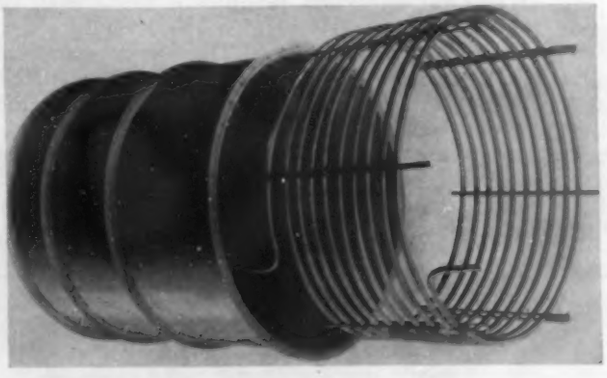


Fig. 8—Acetylene Welded Coil and Tank Used in Conjunction with It

1/8 in. all the way round. The welding was started just ahead of one of the tacks, and as the welding progressed, an ample amount of flux was used dry by dipping the heated end of the rod into the flux can. This was done for the reason cited above, that is, penetration and reinforcement on the bottom side without blowholes or oxidized metal. After welding was started, it was continued without interruption until completed. The piece was allowed to cool slowly, then a roughing and finishing cut taken on the inside, the welding having been done from the outside, showed no sign of blowhole or seam. The assembly has since been giving satisfactory service at elevated temperatures.

Light Gage Welding

The welding of thin gage metal is not difficult. This is accomplished by flanging the edges slightly less than 90° as shown in Fig. 4, the turned up edges being as short and as nearly the same height as possible. Before assembling, the bottom and top of the seam is painted with the paste flux mentioned above. No welding rod is needed, the edges merely being melted down with the acetylene flame. The crevice left on the underside is filled in, either with soft solder, silver solder, yellow brazer, or white brazer, depending on the corrosion problem involved. A seam of this type would be used in making long seams on thin gage sheets and in making of sphere floats by welding two half-sections together. One torch manufacturer has a line of torches whose vital parts are made of Monel metal because of its inherent toughness and strength. The handle formed from strip rolled into a cylinder is welded by using the edge weld described above, of course, fluxing before welding.

Piping and Tubing

Coils are a necessity in many of the process industries, carrying the chemical on the one side, and either a heating or cooling medium on the opposite side. Seamless tubing and pipe is available in all three high nickel alloys for just such coil or manifold work. In the fabrication of these, there are several types of joints usually used. With pipe or heavy walled tubing, gas welding is practical, the ends being beveled to a total of 90° then tacked on opposite sides with an even spacing of about 1/16 in. to 3/32 in. at the base of the vee depending on the diameter and wall thickness. A straight butt joint is used, no jigging being necessary. A typical welded nickel coil made as just outlined is illustrated in Fig. 8.

For the higher walled tubing, the joint is made with silver solder, either as a sleeved joint or a bell and spigot joint. The most important requisite is that the fit be good, that is, not tight on one end and loose on the other, but fit over the entire length. The higher grades of silver solder are remarkably free flowing on these metals and penetrate very quickly to considerable depth, the thin film between two closely fitted surfaces giving excellent strength and a sound joint with a minimum of solder. Thus used, silver solder is not too expensive. It, of course, should not be laid on heavily in a loosely fitted joint.

Silver Soldering

Smaller storage tanks, as well as dyeing machines of all types and sizes for the textile industry, are made of light gage metal, 0.050 in. or lighter and are fabricated by lock seaming and silver soldering. Silver solder is resistant to many of the corrosive conditions to which the high nickel alloys are resistant. After the tank is entirely lock seamed, the seam is fluxed, top and bottom, to aid in the flow of the silver solder and dissolve the oxide on the underside. The flux used for this purpose is that mentioned above, being applied in thin paste form. Here again this flux is preferred to borax because the latter does not keep the metal as bright nor is it as easily removed. A silver solder of low melting point was developed in a cooperative research between Handy & Harman and The International Nickel Company. The flow point obtained, 1325° F. is valuable to prevent cracking the Monel and nickel. Solders of higher melting point are dangerous because they entail working in the red short range.

For this type of silver soldering we ordinarily use a very small oxyacetylene torch, or, better yet, a lead burner's torch. The brazing goes along just as though welding, keeping only a small portion of solder molten, and always keeping the torch moving, preferably in line with the seam. The tip of the luminous flame is kept close to the surface of the pool. In doing this we avoid unnecessary heating of the sheet by the large envelope of the flame by getting the hottest part of the flame where it will do the most work quickly. Silver soldering does work somewhat faster than welding.

In the use of oxyacetylene flame in silver soldering it should never be forgotten that the concentration of heat in a properly regulated flame is enormous and that the flow point of silver solders is much below the flame temperature. Too much heat is dangerous on these alloys. The sheet metal should never be hotter than necessary to thoroughly flow the silver solder, otherwise the sheet may be cracked. With proper care no difficulty will be experienced. Work should start about 2 in. or 3 in. from an edge and proceed toward the edge, to avoid serious difficulty.

Brazing

Just recently a white brazing rod has been developed in the Union Carbide Laboratories which more nearly matches Monel and nickel in color than any previous rod and which has good corrosion resistant properties. Its strength and ductility are good. It fills in that gap between silver soldering and welding rod, flowing at about 1900° F., which is above the hot short range. This relatively high melting point is in its favor, since when brazing with it, the braze will have solidified and contracted slightly before reaching the hot short range of the sheet metal, at which temperature any considerable amount of strain might cause cracking.

In conclusion, it is obvious that the use of the oxyacetylene flame in joining the high nickel alloys is entirely practical for a wide variety of seams and forms of metal. The variations on the above general principles which can be made are many and the writers heartily endorse the use of this means of fusion in the manufacture of chemical apparatus.

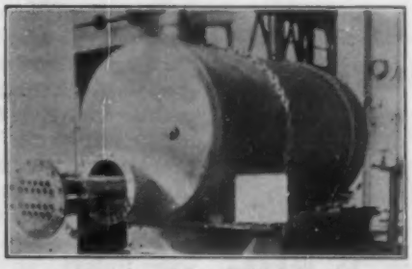
1. Cylinder formed and welded longitudinally on the outside

2. Rounding cylinder after inside and outside welding

3. Cylinder with manhole head welded in

4. Port for heating unit welded up the side, with flange welded on

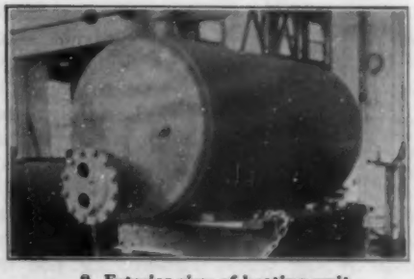
5. Port for heating unit welded into the tank



6. Tank completely welded; heating unit being inserted

7. Welding is completed; manhole cover inserted

8. Various fittings applied to completed tank



9. Exterior view of heating unit bolted on

10. Completed tank installed

Constructing a 500-Gallon Welded Everdur Tank

By C. B. JACOBS, Jr.

†Mr. Jacobs, Jr., is connected with The American Brass Company, Sales Promotion Department.

EVERDUR Metal, a copper (96%) silicon, manganese alloy, is increasing rapidly in use as a tank material.

Everdur combines the useful characteristics of both steel and copper. It possesses the strength of steel, is immune to rust and equals copper in general corrosion resistance. Everdur is readily weldable by all the commonly used gas and electric methods and for other fabricating operations is handled by the same methods used with steel. The majority of Everdur tanks are built by some method of welding. However, a number of large vessels have been of riveted construction. The largest tanks in service were oxyacetylene welded.

To give a condensed description of metal arc welding technic with Everdur, we will discuss the construction of a medium-sized tank. This tank, which was fabricated by The National Pipe Bending Company, New Haven, Connecticut, is in service as a hot water storage tank in an office building. The tank is eighty-four inches overall and forty-two inches in diameter, providing a capacity of five hundred four gallons. Both the shell and the heads are of three-eighths inch metal. The heads were dished and flanged. The heating unit is in the tank.

The shell was formed from a single plate in the same manner as if the material was steel. The longitudinal seam was of a single vee type. The welding was done with a three-hundred ampere capacity arc welder, using reversed polarity and five-thirty-seconds inch Everdur welding rod. The vee groove on the outside of the shell was filled with a single bead, the welder moving his arc in an elliptical path. This is necessary because Everdur flows more freely than steel and if the arc was played on the top of the molten metal, the metal would flow

rapidly in front of the arc. To prevent this, the welder built up a portion of the bead, then dropped the arc into the unwelded groove and brought it back again over the top of the metal just deposited. A water filled copper tube was used as a backing plate.

When the V was filled, another bead was run on the inside of the seam. The outside bead was peened with an air hammer. The peening reduced the height of the bead and densified and strengthened the weld metal.

The heads were pushed inside the shell and fastened with lap welds. Beads were run around the girth seams both inside and outside. A port for the heating unit was welded to one head by a single pass.

This tank was tested to three hundred pounds hydrostatic pressure for a working pressure of one hundred twenty-seven pounds.

The foregoing procedure has been found to produce successful results with tanks of that capacity. Where thicker metal is used, the seams are usually built up in a series of courses, each approximately one-quarter of an inch thick. Each course is peened separately and the final course annealed with an oxyacetylene torch. The preceding courses are annealed by the heat of the bead laid over them. For oxyacetylene and carbon arc welding, the procedure, of course, differs in certain essentials.

A Reply to the Discussion on Paper by Wilmer E. Stine on "Factors Affecting the Weldability of Steel"

By **W. E. STINE**

†Mr. Stine is connected with the Lincoln Electric Company, Cleveland. His paper was presented at the 1931 Fall Meeting of the A. W. S. and was published in the September, 1931, issue of the Journal.

MR. LLEWELLYN, in criticizing my paper, attempts to discredit the conclusions and theory set forth in the paper, on the basis of tests made by the Carnegie Steel Company on four heats of steel.

While the ingots from each of the four heats were treated in five different ways, only two kinds of treatment, "A" and "B," can be said to be representative of commercial practice. The other ingots may be interesting from the development point of view but are of doubtful value when studying welding characteristics of commercial steel. I do not believe that the addition of silicon to ingot moulds will yield results comparable to the general practice of adding silicon to the furnace or ladle.

Furthermore, it is evident that in analyzing the data obtained on two of these four heats (heats I and II) Mr. Llewellyn overlooked factors, pointed out in the paper, which play a major part in causing porosity of welds made in steel of the class in which these two heats fall.

The conclusions as set forth in my paper were based on a detailed study of 76 heats of commercial steel furnished by various manufacturers and a general study of commercial welding over a period of several years. While we do not feel that even the result of our tests on 76 heats enable us to state the absolute answer to this subject, we feel that it points the general direction more conclusively than the results of tests on a few special steels reported by Mr. Llewellyn.

We would like to see more research work along this line undertaken.

In view of some of the points raised and criticisms made of my paper, it appears that some parts of the paper were not clearly understood and that the material and tests upon which some of the criticisms were based were not prepared or conducted in a manner to yield data which would warrant the apparent contrary conclusions reached by some of my critics.

I would like therefore to explain more fully a few points, as well as answer some of the criticisms.

The paper was presented as a summary of the results of rather extensive laboratory investigations of some of the elements in steel that affect the arc welding characteristics. We omitted much of the detailed data, as well as description, and results of tests, which did not seem to yield any significant information.

In our second and third series of samples, including plates from 18 heats, we made all the tests and examinations listed by Mr. Llewellyn, except X-ray examinations of welds. In addition to the tests listed by Mr. Llewellyn we tested the second series of plates for normality and all welds were broken open and examined.

Due to the volume of work involved and apparent lack of value of some of the data, we did not make all of these tests and examinations on all the samples of plates in our fourth series which included plates from 58 heats of steel.

Referring further to Mr. Llewellyn's discussion, it seems that the principal difference in the method of conducting the investigation was that Mr. Llewellyn made "beads" or "welts" on solid plates $^1/_2$ in. thick, and X-rayed them to determine their porosity, while we welded two plates together and broke them open and examined the fractured weld.

From the welding current, voltage and speed given by Mr. Llewellyn, it is evident that the fused metal penetrated or extended less than one-half way through the plates.

Since in exographs cavities appear only in their relative proportion to the thickness of the plate, it would seem that the effectiveness of the X-ray method of studying porosity of welds would have been considerably increased if the penetration of the weld metal through the plate had been complete or nearly so.

One conclusion arrived at and reported in the paper but not actually listed under the heading of "conclusions" is quoted from the paper as follows:

"It was also found that the weld metal in dead soft steel may be porous due to gas holes unless a slag-forming flux is used to cover the weld metal while it is molten.

"Figure 8 shows such a weld . . . . . As previously pointed out, a very low carbon steel has a high capacity for gases at high temperature. . . . ."

In this connection, I would like to quote from Dr. Colin J. Smithell's book entitled "Impurities in Metals," which was referred to in the paper (Table 12, opposite page).

If we plot these data as in Fig. 11, it will be evident that when the carbon content of the steel is in the range

below 0.15%, the carbon will be a large factor in causing porosity of welds; and in view of the results of our tests using slag-forming fluxes on such steel, it is evident that any slag-forming material of the proper consistency or a heavy iron oxide scale on the plate or the relative amount and composition of non-metallic inclusions in such steel will have a further influence on the porosity of the weld metal.

Table 12.—Effect of Carbon Content on Amount of Gas Absorbed by Steel

Carbon Content per Cent	Volume of Gas in Cc. per 100 Grams of Metal
0.04	2.43
0.13	.86
0.44	.68

Approximately one-half of the steel used by Mr. Llewellyn in his investigation falls within this range. We believe, therefore, that carbon and the quantity and consistency of the non-metallic inclusions are major controlling factors in Mr. Llewellyn's heats I and II.

Since in these heats Mr. Llewellyn added the silicon to the ingots it might be expected that the steel from D and E ingot would contain more SiO_2 slag-forming material than would be found in commercial steel of the same total silicon content. Because in the latter case, the silicon is usually added in the furnace or ladle and consequently the SiO_2 has more opportunity to escape from the bath.

Mr. Llewellyn's report on the results of their welding tests of ingots IE and IIE, to which he added both aluminum and silicon in relatively small quantities in the ingot molds, seems to confirm the results reported by the author in an article published in *Metal Progress* of August, 1931, pages 91 to 94. When both aluminum and silicon are added at the same time the product of oxidation may be an aluminum silicate good slag-forming material and there seems to be some indication that the gas solubility of the steel is not affected in the same manner as when aluminum or silicon are used alone. There should be further research along this line.

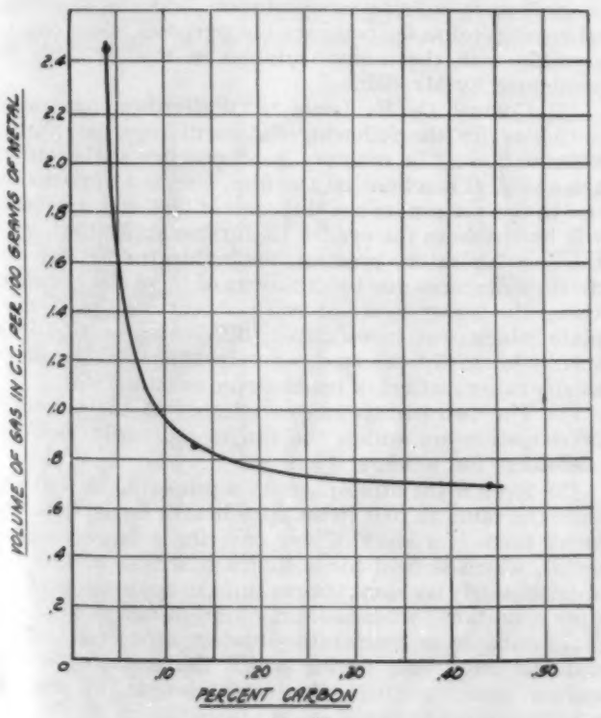


Fig. 11

In view of the pronounced effect of carbon on the solubility of gases in steel, when the carbon is in the range below 0.15%, as described above, we feel that the effect of aluminum, silicon and manganese, can best be determined by a study of steel having more than 0.15% carbon.

Mr. Llewellyn reports that in a certain metallic arc welding process, steel having a silicon range of from 0.06 to 0.08% has been found most satisfactory. In view of the fact that in metallic arc welding, the weld metal is made up of fused electrode, fused parent plate, and in some cases, fused metallic ingredients from the flux, we would be interested in knowing what the silicon and manganese content of the resulting weld metal is in the cases referred to.

Since in most cases metallic arc electrodes are made from rimmed steel without the addition of any aluminum or silicon, in which cases the silicon content of the electrode is usually less than 0.015%, the silicon content of a metallic arc weld in steel plates having 0.06 to 0.08% silicon will be considerably less than 0.06%, depending upon the ratio of the fused base metal and the fused electrode.

As a general rule, the higher the welding speed, the higher the percentage of fused parent plate and the greater the influence of the quality of the plate on the resulting weld metal.

The difficulty of an accurate analytical determination of aluminum content of steel was pointed out in the paper. The following are typical of analysis made in the laboratories of The Lincoln Electric Company. Each sample was taken from a different heat:

Data by Steel Maker: C, per Cent	Aluminum Added Oz. per Ton	Analysis by the Lincoln Electric Co. Total Al, per Cent
0.05	None	0.006
0.19	None	0.005
0.21	1.6	0.005
0.20	3.5	0.010
0.13	5.5	0.018
0.16	5.5	0.020
0.11	16.4	*0.005
0.19	16.4	**0.025

* Fairly good welding quality.
** Poor welding quality, due to gas holes.

The addition of 3.2 oz. per ton is equivalent to the addition to 0.01% of aluminum.

We have found some indications that the addition of aluminum to steel facilitates the formation of nitrides in the weld metal.

We note that Mr. Llewellyn reports best results from IV D ingot. While, in view of our tests, 0.10% silicon appears a little high for 0.26% C steel, we assume that in this case the silicon was added in the ingot moulds in which case the silica (SiO_2) would be proportionately higher than in commercial steel, where the silicon is usually added in the furnace or ladle.

Referring to the discussion by Dr. Herty, I would like to point out that in arc welding much of the fused metal is raised to a temperature considerably above the finishing temperature of an open hearth heat, and therefore in cooling, it must fall through the finishing temperature of an open hearth heat. Then it must follow that if the steel is of such composition that it was in approximate chemical equilibrium at the finishing temperature of the open hearth heat, it will after welding reach chemical equilibrium by cooling if there is no major change

in its composition before solidifying. The further oxidation of carbon at the higher temperatures raises the temperature at which equilibrium will be reached.

I doubt whether the atmosphere in a properly shielded arc is greatly different than that in an open hearth, except that the temperature is higher.

As to whether SiO_2 is available for establishment of chemical equilibrium at high temperatures, attention is invited to the apparent chemical equilibrium established in the acid open hearth furnace under a slag which is largely SiO_2. When the carbon falls to about 0.15% the bath remains dead, the silicon and carbon content remains approximately constant. The average of 50 such heats was reported by one investigator as 0.15% carbon and 0.016% silicon. In this case silicon appears to be dissolved from the slag, establishes equilibrium and prevents further reduction in the carbon.

In conclusion, it seems that the addition of aluminum alone in the moulds is harmful to steel for arc welding purposes for the following reasons:

(*a*) Melting temperature of Al_2O_3 is so high that it causes slag holes in welds.

(*b*) Facilitates the formation of nitrides in weld metal.

(*c*) May cause gas holes in weld metal.

A small addition of silicon seems beneficial and is less harmful than aluminum. The silicon present should not exceed a certain amount, which is governed by the requirements for sufficient oxygen to be in chemical equilibrium with the carbon present at a temperature slightly above that of solidification of the weld metal.

Further research is needed to determine whether better steel for arc welding can be obtained by the use of compound or complex deoxidizing materials which do not increase the solubility of the steel for certain gases present during arc welding.

Comments on Reply by Mr. W. E. Stine to the Discussion of His Paper on Factors Affecting the Weldability of Steel

By F. T. LLEWELLYN

†Mr. Llewellyn is connected with the United States Steel Corporation.

I PROPOSE to comment on Mr. Stine's reply to the discussion of his paper under five heads:

(1) He questions the value of the Carnegie Steel Company investigation on the ground that some of the treatments were not representative of commercial practice in that the addition of silicon in the ingot moulds would not yield results comparable to those obtained in the general practice of making the addition in the furnace or in the ladle.

(2) He is of the opinion that his investigation, based on experiments with 76 heats of steel, produced by various manufacturers, yields more reliable information than the investigation on the four special heats reported by me.

(3) He questions the effectiveness of the X-ray method of studying porosity in the Carnegie investigation on the ground that the fused metal extended less than half way through the plate.

(4) He discusses the effect of the carbon content on the solubility of gases in the steel.

(5) He apparently takes issue with Dr. Herty's argument that equilibrium conditions in an open hearth furnace are not similar to those incident to arc welding.

Referring to each of these features in sequence I would point out:

(1) The relative amounts of silicon, silica and silicates in steel to which silicon is added in the furnace or in the ladle, as compared with those in steel to which silicon is added in the mould, depend more on the temperature and the degree of deoxidation of the steel before the addition is made than on the method of making the addition. Microscopic examination of the steels reported in my discussion showed them to be free from excessive amounts of impurities, and the amount of inclusions in the steel to which a large addition of silicon was made in the mould was not noticeably greater than in steel from ingots to which no silicon addition was made. Micrographs taken at 100 diameters before and after etching are on file at the Carnegie laboratories and may be examined by Mr. Stine in order to confirm this statement.

(2) On account of the elimination, as far as desirable practice warrants, of all variables in manufacture and composition, except those under investigation, the results obtained by the Carnegie metallurgists are capable of more definite interpretation, and are, therefore, of greater value for comparative purposes, than can be possible with the many variables in the 76 heats investigated by Mr. Stine.

(3) Colonel G. F. Jenks of Watertown Arsenal is authority for the following statement regarding X-ray examination: "In ordinary good practice variations in the chemical reactions on the film, due to a variation of one to two per cent of the thickness of material traversed, will be visible to the eye." He further states that, with the best laboratory practice, the highly trained eye can detect differences due to variations of $^1/_2$ of one per cent. Using the higher figure of two per cent, on the $^1/_2$-inch plate which was investigated, differences of 0.01-inch should be easily detected. Surely this is as sensitive as any other method of macroscopic examination.

(4) The two carbon ranges selected in the Carnegie investigation are within the ranges ordinarily used by customers for welding steel.

(5) Even if the atmosphere in a properly shielded arc were the same as that in an open hearth furnace, in the latter there is a layer of slag covering a large mass of metal, which is held for a sufficient length of time at approximately constant temperature to approach equilibrium conditions, whereas in any kind of fusion weld the rapid changes in temperature and in other conditions, and the short time during which the metal is in the molten state, prevent the establishment of similar equilibrium conditions.

Altering Wrought Iron and Steel Bridges by Welding

By FRANK P. McKIBBEN

✦Paper presented at the Annual Convention of the American Road Builders Association by Frank P. McKibben as representative of the AMERICAN WELDING SOCIETY.

PREVIOUS to the transition period approximating the years 1885–1890, the principal metal used in metallic bridges was wrought iron; but since that time, practically all metallic highway and railway bridges have been made of steel. Steel was first used in the Eads Bridge at St. Louis in the early seventies, but this was very unusual.

So far as the present study is concerned, wrought iron is pure iron. The amounts of carbon, silicon, sulphur and manganese contained therein are negligible; but introduction into the iron of very small amounts of these elements produced steel, and resulted in one-third to one-half greater tensile strengths. Changes in manufacturing methods lowered costs of production. So that by 1890, soft or medium steel containing approximately 0.15 per cent carbon came into general use for structural work. In recent years, copper-bearing and other alloy steels, such as those containing nickel or silicon, are coming into use.

Of the many wrought iron bridges and early steel bridges in service at present, some are now inadequate because of corrosion or because of great increases in loads to which they are subjected. In 1885 a loaded wagon weighing five or six tons was considered a reasonable live load for use in proportioning highway bridges not subjected to electric cars. In 1930, the writer used thirty-ton trucks in designing the floor system of a large bridge in a city where twenty-ton loaded trucks were then in service. Thus have the loads increased.

In many cases, these highway or railroad bridges can be given a very considerable increased longevity by repairing or reinforcing with the aid of welding.

Causes Which Necessitate Alterations

The influences which cause alterations may be thus classified:

1. Corrosion.
2. Cracks due to overloading or to defective metal.
3. Excessive stresses.
4. Re-adjustment of existing members.

Corrosion

Wrought iron bridges seldom become inadequate because of corrosion, but steel bridges frequently suffer from this influence. Rust on wrought iron takes the form of small spherical particles, easily brushed off; whereas on steel, it appears in large sheets or laminations of oxides, sometimes as thick as $^1/_4$ in. And as this deterioration is usually localized—as, for example, at supports where the metal is in contact with earth, at points where wooden floors cover steel stringers or floor beams, at places where planking is in contact with or close to girders or truss members, or at contact points between concrete and steel—the addition of new material welded in place is efficacious.

Figure 1B illustrates a simple use of welding to add a new plate to an inclined end post of a highway bridge in Pennsylvania where corrosion had formed a hole 2 in. by 16 in. in a channel web. A short reinforcing plate was placed inside of the post and welded to the channel.

One of the most interesting applications of welding to replace corroded metal is that of the New York Central Railroad's overhead highway bridge M-4-A, at Brook Avenue, Borough of Bronx, New York City, Fig. 2. This structure, as well as Bridges M-1 at East 163rd Street, and M-8 at East 149th Street, had exposed girder lower flange plates badly corroded by gases from locomotives passing underneath. The old flange plates were

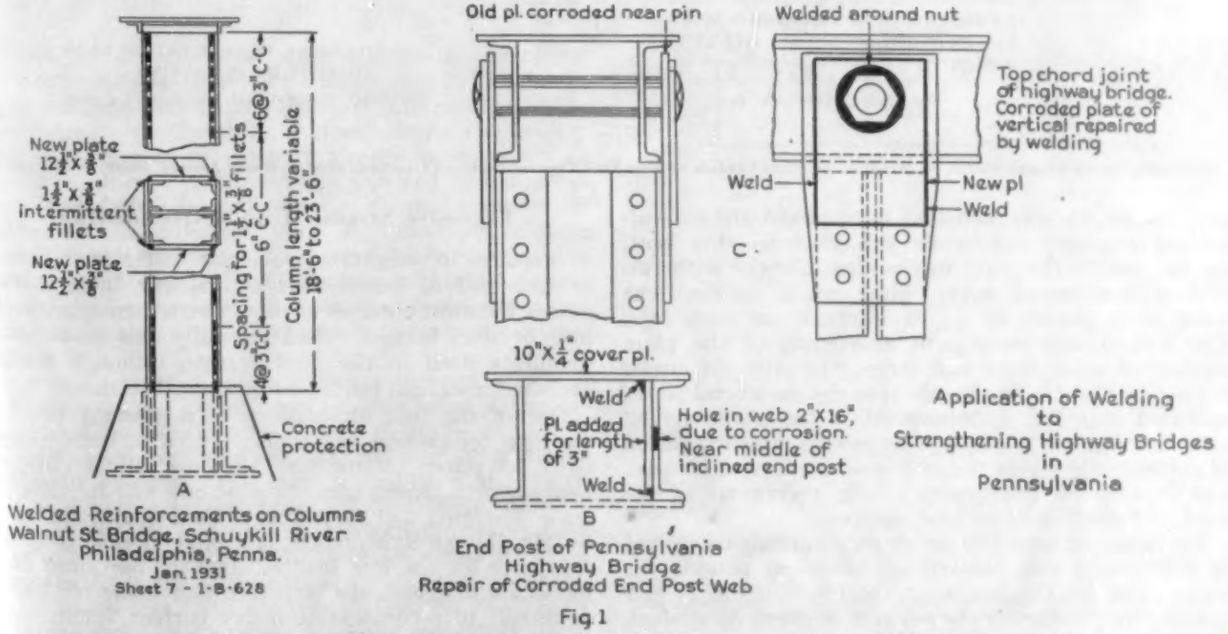


Fig. 1

Reinforcing a Channel Web of a Truss End-Post Where Corrosion Had Formed a 2 in. x 16 in. Hole in the Web

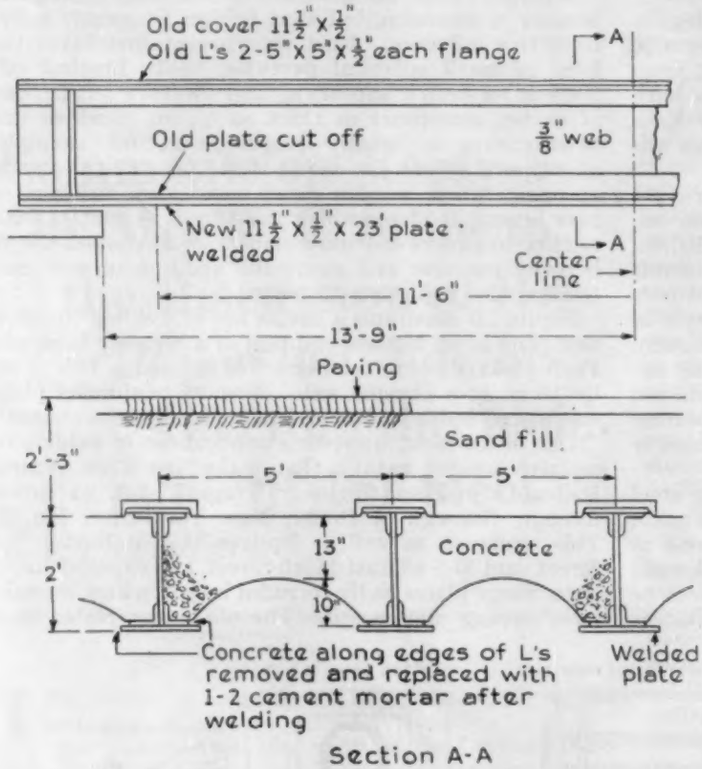
removed, a few at a time; the old steel was thoroughly cleaned, and old exposed rivet shanks chipped off; then new flange plates were welded in place of the old ones without appreciably disturbing the concrete arches in contact with the girders, except in so far as necessary to provide places for clamps. But as the dead load stresses in the bottom flanges were large, it was necessary in applying the new plates to give them an initial dead load stress comparable with that in the bottom flange angles from which the corroded plates were removed and to which the new plates were welded.

This transfer of stress was accomplished by first clamping the new plate to the old angles; then, with two welders operating, a 30-inch continuous fillet was deposited on each side at one end of the new plate to weld it to the angles. With the plate clamped in position and thus welded at one end, it was heated with torches

Cracks Due to Overloading or to Defective Metal

Defects resulting from cracks are most likely to appear in structural details such as angles connecting stringers to floor beams; or top flange angles on stringers of railroad bridges which crack horizontally along the junction of vertical and horizontal legs due to bending of the latter resulting from flexture of track ties resting directly on the angles.

Figure 4 presents the Pennsylvania Railroad's method of strengthening the outstanding legs of stringer upper flange angles by welding triangular bracket plates after the cracked material is cut out and replaced by depositing weld metal at the root of the angle. This method of adding metal to the root of angles is also applied where the angles exhibit weakness but are not cracked.



Increase in length of flange plate :-

Due to stress = $\frac{SL}{E} = \frac{11000(23)12}{30000000} = 0.10"$

Due to temperature = DCL

$DCL = \frac{SL}{E}$

$D = \frac{S}{EC} = \frac{11000}{30000000(0.000007)} = 52°F.$

or DCL = 0.10"; $D = \frac{0.10}{0.000007(23)12} = 52°F.$

S = unit stress

L = length of plate

E = modulus of elasticity

D = degrees fahr.

C = coef. of expansion

New York Central Railroad
Under Brook Ave.- Boro. of Bronx
Between E. 157th and E. 159th Streets
107 Girders Repaired by Welding

See Eng. News-record, Oct. 24, 1929
Article by H.T. Welty
Method patented by A. G. Leake

Fig. 2

Replacing Lower Flange Plates, by Welding, on Plate Girders at New York Central Railroad Overhead Bridge, Brook Avenue, Borough of Bronx

until its length was increased by a predetermined calculated amount, and while subjected to this heat, the free end of the plate was welded, likewise with two 30-inch continuous welds, after which intermittent welds were placed at 3-inch intervals on each side. The cooling and consequent shortening of the plate transferred some dead load stress from the old angles to the new plate. Strain-gage readings on several plates indicated that the stress induced in the plates agreed with that desired. Clearly, this process of heating need be applied only where the unit dead load stress is large, that is, where it constitutes a large percentage of the combined dead and live load stresses.

The increased length in inches may be easily computed by multiplying the desired unit stress in pounds per square inch by the length of the plate in inches and dividing the product by the modulus of elasticity of steel, 30,000,000.

Excessive Stresses Due to Overloading

Increases in weights of vehicular traffic on highway bridges and of locomotives on railway bridges constitute the most common cause of strengthening wrought iron or steel bridges. And generally this inadequacy manifests itself in the floor system, although trusses are sometimes light for the duty imposed on them.

One of the best illustrations of reinforcing bridges, too light for present-day traffic, is that of the Chicago Great Western Railway's Missouri River Bridge, Leavenworth, Kan., consisting of one 440 ft. through draw and two 330 ft. through fixed spans, designed by Mr. George S. Morrison, and built in 1893 (Fig. 5). Adequate for the live load of 3000 lb. per linear foot for which designed, the structure had to be reinforced or rebuilt to accommodate heavy current traffic. Between the dates of February 28 and April 28, 1927,

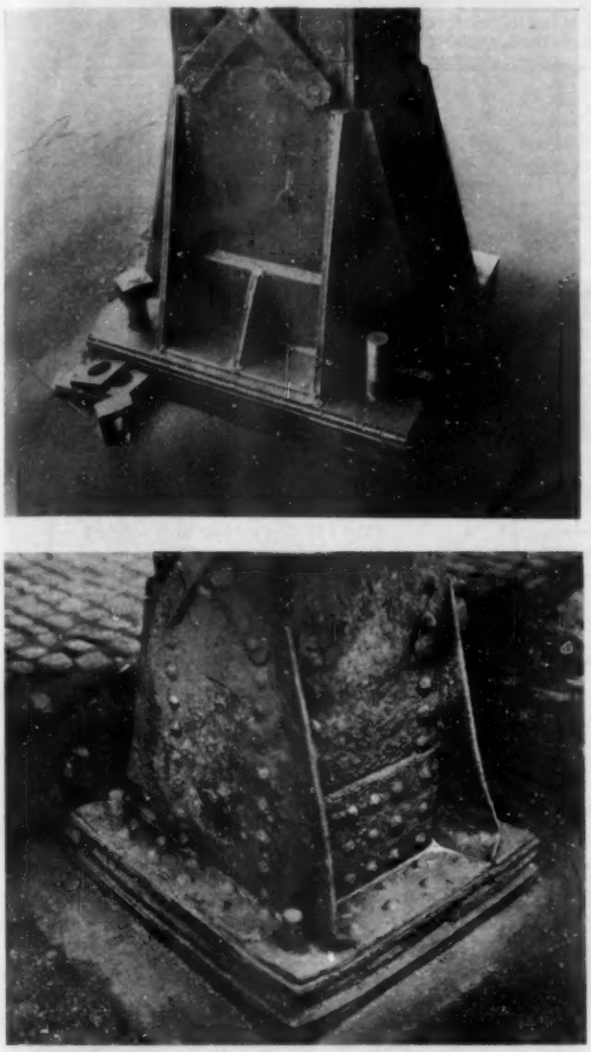


Fig. 3—Replacing Corroded Bases, by Welding, on Pennsylvania Railroad Jersey City Elevated Structure

225,000 lb. of structural steel reinforcing, involving the use of 2000 lb. of welding wire to deposit 7500 linear ft. of welding, were applied without interruption to the heavy traffic of the three railroads using the bridge. This strengthening provided for a single locomotive with 55,000 lb. on each pair of drivers, followed by a uniform train-load of 4000 lb. per linear ft. Figure 5 showing the welded details indicates that additional plates were welded to top chords and end posts of fixed spans, to bottom flanges of all stringers, to top and bottom flanges of all floor beams; and that changes were also made in top flanges of all stringers and in parts of the lateral system.

The addition of a narrow plate to the top, and of a wide plate of the lower flange of floor beam is the arrangement frequently used, and is desirable in that it permits downward (horizontal) welding and avoids over-head welding. The same procedure is illustrated in Fig. 6 noting several other Chicago Great Western Railway bridges, and in Fig. 7 which illustrates floor beams on a Pennsylvania Highway Department bridge strengthened in the same manner.

Fig. 7 also sets forth a clever method for raising, by means of jacks, the existing stringers and planking in order to replace the upper flange reinforcing plate on the floor beam and to insert nine lines of new stringers.

Re-adjustment of Existing Members

This refers particularly to shortening inactive eyebars in pin connected bridges, that is, eyebars which are too long and require shortening to make them carry their proportion of the stress in a given truss member. The Pennsylvania Railroad has applied this to several pin-connected trusses, notably the Delaware River Bridge, Philadelphia, where inactive eyebars 12 in. by $1^{7}/_{8}$ in. were shortened with the aid of adjustable yokes bolted to the eyebar and abutting against bearing plates, ShP, Fig. 8, previously welded to the eyebar. By adjusting the turnbuckles the stress is removed from the enclosed portion of the eyebar after which a short section of the main bar is taken out, and two splice plates SP added by welding. The bolted yoke is then removed.

This is a modified form of a somewhat similar device used on a Pennsylvania Railroad bridge on the Conemaugh Division, as illustrated by sketch in right side of Fig. 8.

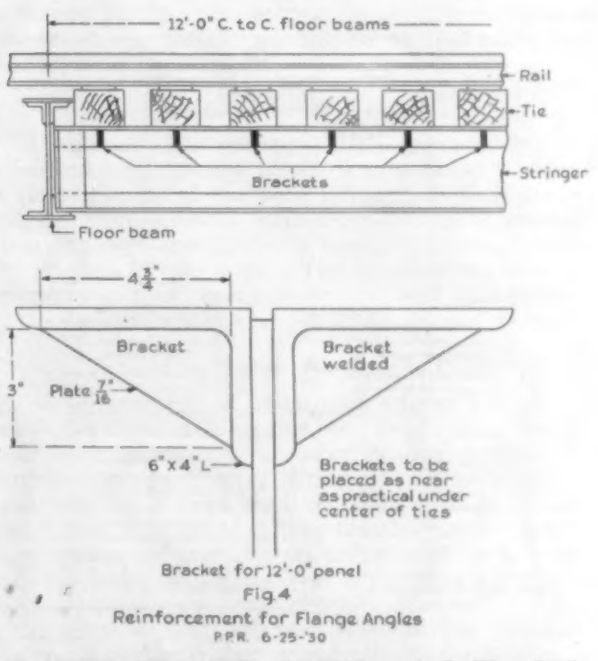
Welding Solves Many Problems

Wrought iron or low carbon steel of which the older metallic bridges are built are easily welded.

Welding is used in cases similar to those described in this paper because it results in economies. In general, it is by far the cheapest and best method available.

If arc-welding is used, the proper current may be supplied by a generator driven by an electric motor if electric power is available or by a gas engine if no electric line is at hand. For hand-welding wrought iron or low carbon structural steel, using a $^{5}/_{32}$ in. bare wire electrode, the amperage should be about 160 to 180 when depositing $^{1}/_{4}$-in. to $^{3}/_{8}$-in. fillets on steel of $^{1}/_{4}$ in. to $^{3}/_{8}$ in. thickness; the lesser current for the smaller, and the greater for the larger fillets and thicknesses.

If bare electrodes are used their chemical composition should be approximately as follows: carbon, 0.13 to



Reinforcement for Outstanding Legs of Flange Angles Where Loads Directly Applied to Top Flanges Form Cracks at the Roots of the Angles

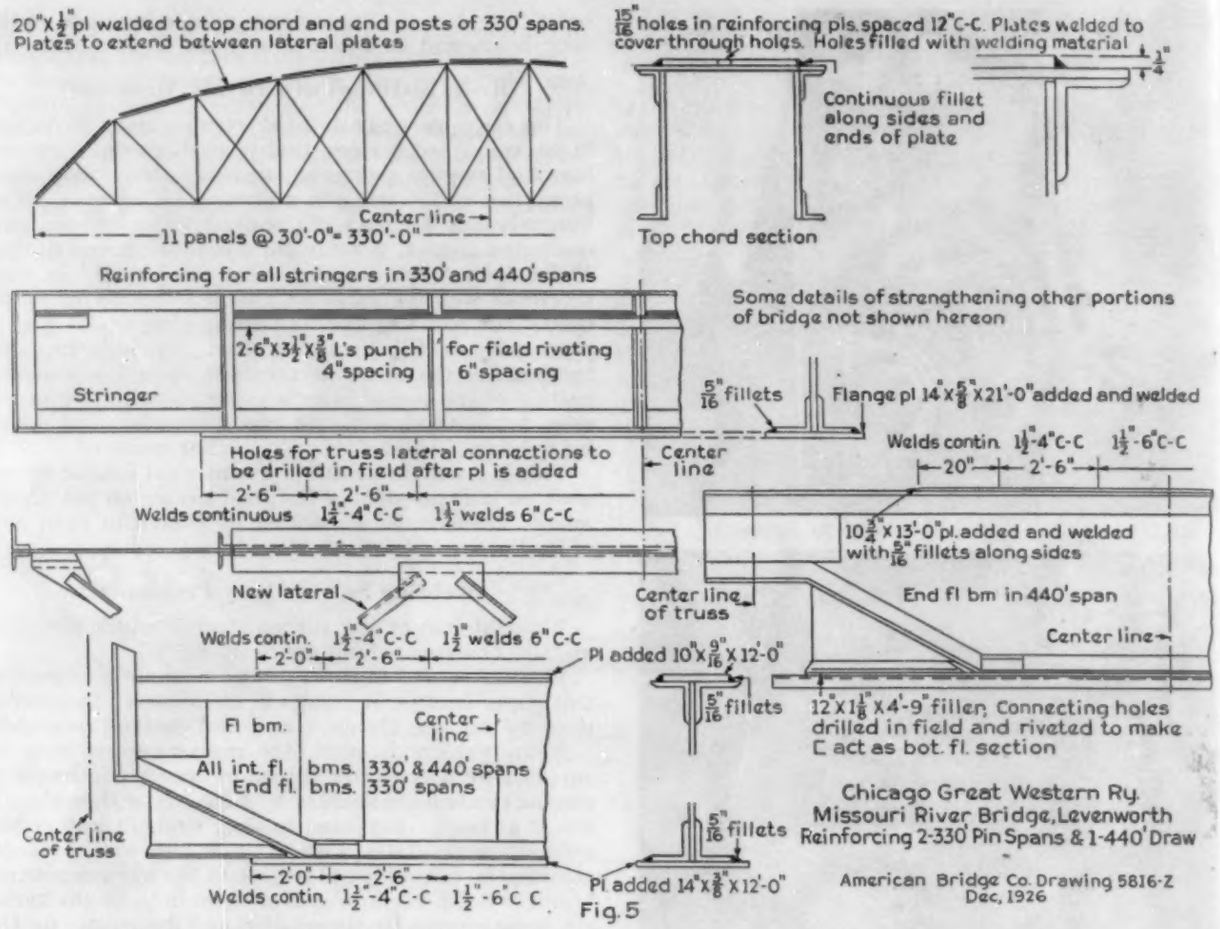
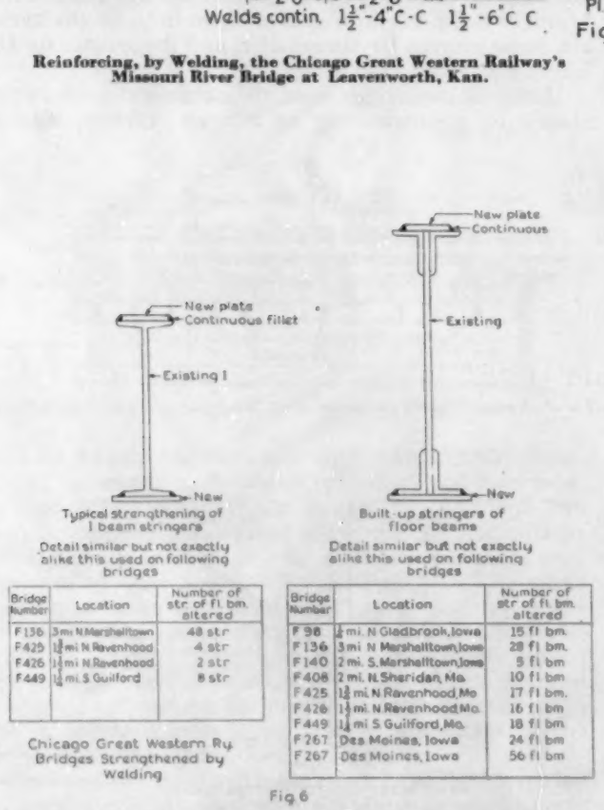

20"X½" pl welded to top chord and end posts of 330' spans. Plates to extend between lateral plates
Center line
11 panels @ 30'-0"= 330'-0"
15/16" holes in reinforcing pls. spaced 12" C-C. Plates welded to cover through holes. Holes filled with welding material
Continuous fillet along sides and ends of plate
¼"
Top chord section
Reinforcing for all stringers in 330' and 440' spans
Stringer
2-6"X3½"X⅜" L's punch 4" spacing
for field riveting 6" spacing
Some details of strengthening other portions of bridge not shown hereon
5/16" fillets
Flange pl 14"X⅝"X21'-0" added and welded
Welds contin. 1½"-4" C-C 1½"-6" C-C
20" 2'-6"
Holes for truss lateral connections to be drilled in field after pl is added
2'-6" 2'-6"
Center line
Welds continuous 1¼"-4" C-C 1½" welds 6" C-C
10¾"X13'-0" pl. added and welded with 5/16" fillets along sides
New lateral
Center line of truss
End fl bm in 440' span
Center line
Welds contin. 1½"-4" C-C 1½" welds 6" C-C
2'-0" 2'-6"
Pl added 10"X9/16"X12'-0"
5/16" fillets
12"X1⅛"X4'-9" filler; Connecting holes drilled in field and riveted to make C act as bot. fl. section
Fl bm.
Center line
All int. fl. bms. 330' & 440' spans
End fl. bms. 330' spans
Center line of truss
5/16" fillets
Chicago Great Western Ry.
Missouri River Bridge, Levenworth
Reinforcing 2-330' Pin Spans & 1-440' Draw
American Bridge Co. Drawing 5816-Z
Dec, 1926
2'-0" 2'-6"
Welds contin. 1½"-4" C-C 1½"-6" C C
Pl added 14"X⅜"X12'-0"

Fig. 5

Reinforcing, by Welding, the Chicago Great Western Railway's Missouri River Bridge at Leavenworth, Kan.

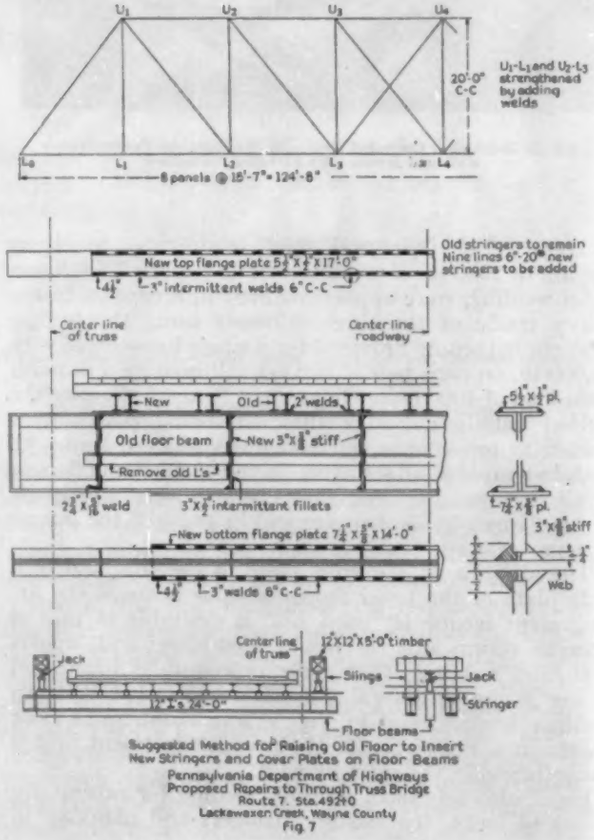


Bridge Number	Location	Number of str of fl bm altered
F 136	3 mi N Marshalltown	48 str
F 425	1½ mi N Ravenhood	4 str
F 426	1¼ mi N Ravenhood	2 str
F 449	¼ mi S Guilford	8 str

Chicago Great Western Ry. Bridges Strengthened by Welding

Bridge Number	Location	Number of str of fl bm altered
F 98	½ mi. N Gladbrook, Iowa	15 fl bm.
F 136	3 mi N Marshalltown, Iowa	28 fl bm.
F 140	2 mi. S. Marshalltown, Iowa	5 fl bm
F 408	2 mi. N. Sheridan, Mo.	10 fl bm
F 425	1½ mi. N. Ravenhood, Mo	17 fl bm.
F 426	1¼ mi. N. Ravenhood, Mo.	16 fl bm
F 449	¼ mi S. Guilford, Mo.	18 fl bm
F 267	Des Moines, Iowa	24 fl bm
F 267	Des Moines, Iowa	56 fl bm

Fig. 6



Suggested Method for Raising Old Floor to Insert New Stringers and Cover Plates on Floor Beams

Pennsylvania Department of Highways
Proposed Repairs to Through Truss Bridge
Route 7. Sta. 492+0
Lackawaxen Creek, Wayne County
Fig. 7

Typical Reinforcement for Upper and Lower Flanges of Stringers and Floor Beams of Chicago Great Western Railway Bridges

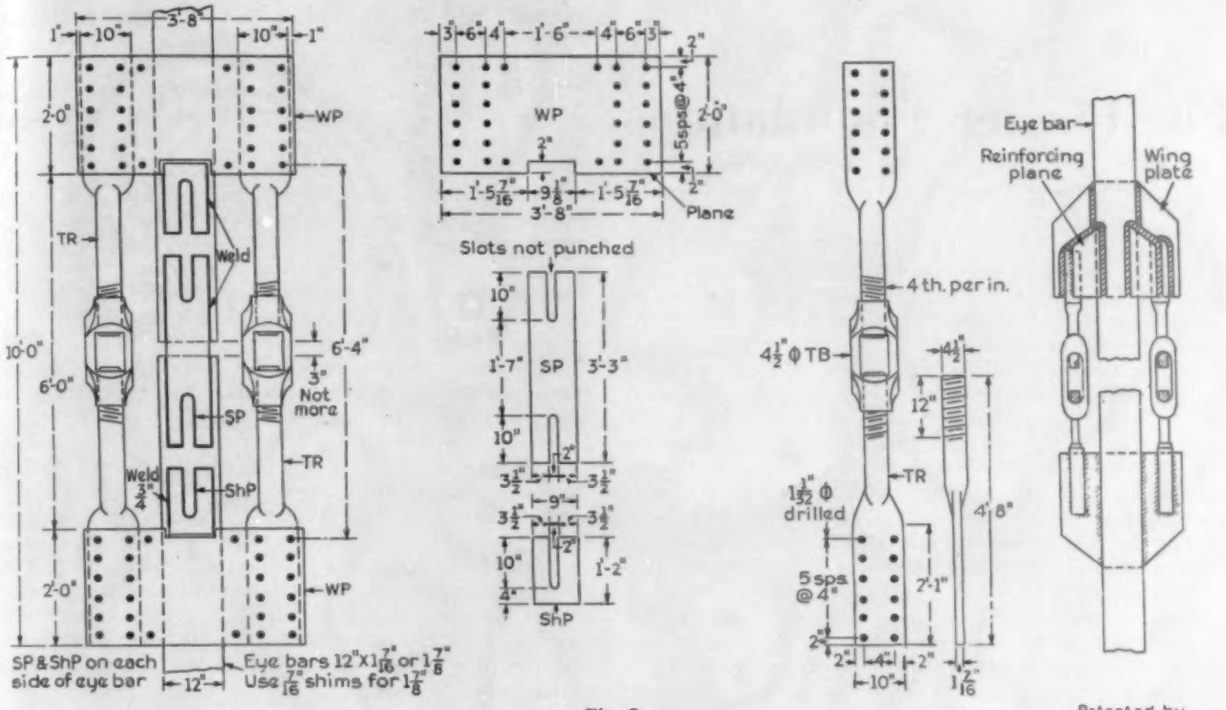


Fig. 8
Delaware River Bridge
P.R.R. 11-10-'31

Devices for Shortening Inactive Eyebars in Pin-Connected Trusses of the Pennsylvania Railroad

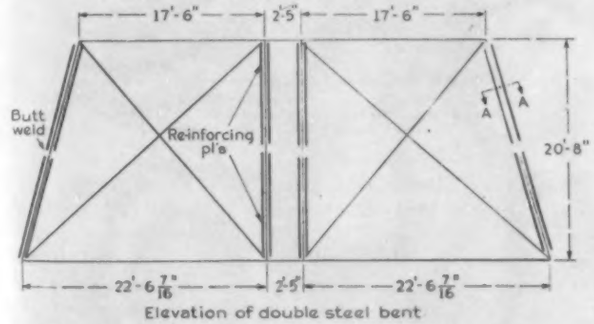
0.18 per cent; manganese 0.40 to 0.60 per cent; phosphorus and sulphur not over 0.04 per cent each; silicon not over 0.06 per cent.

In general, the work to be welded should be the positive, and the electrode the negative side of the circuit.

Corroded iron or steel should be cleaned of dirt, rust and paint before welding is applied; and if corrosion has proceeded to the point of leaving thin edges on angles or other similar parts, the thin portions should be removed till adequate thickness is reached whereon welding may be applied.

Care should be exercised to secure good penetration of the weld metal into the parts welded.

Not infrequently one sees plates welded to flanges of stringers or floor beams with intermittent fillets. As this arrangement permits water to enter between the reinforcing plate and the original flange parts, continuous instead of intermittent welding seems preferable, and not very much more costly.



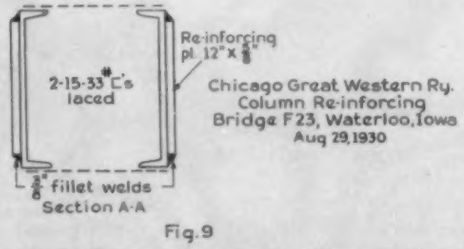


Fig. 9

Reinforcing, by Welding, Columns on Waterloo, Iowa, Bridge of Chicago Great Western Railway

Qualification of Welders

As only capable welders should be employed on important undertakings, all applicants should be tested at the beginning of the work to ascertain their fitness; and, if the project be of sufficient magnitude to warrant, those employed should also be tested at intervals during the progress of the work. The qualification tests for determining their competency are well standardized by the AMERICAN WELDING SOCIETY.

Extent to Which Welding Is Used

The writer's list of welded structures includes 75 bridges in which welding has been used during the last four years to reinforce or alter existing bridges, but doubtless there are many others. On the whole, railroad companies have been much more favorably inclined toward the use of welding than have state highway departments, although several of the latter have become very active during the past year in applying this modern tool to those cases where applicable.

Certainly welding will not solve all the structural engineer's problems, but many opportunities arise in altering wrought iron or steel highway or railway bridges where no other method is so well adapted.

For Firmer Foundations

✦Extracted from February, 1932, issue of *Oxy-Acetylene Tips*.

IN THE actual operation of driving a good length of welded steel pipe piling lies probably one of the most striking demonstrations of the inherent strength of properly made welds.

One method of constructing such piles is to drive in the necessary length of medium diameter pipe, then blow out the earth that is inside the pipe, and finally fill the pile with concrete. In cases where the bed rock lies deeper than the single lengths of available pipe will reach, some means must be used to join the pipe together with a joint sufficiently strong to permit driving the pile to the desired depth. There must not be any possibility of bending, warping, driving crookedly, or being crushed.

Work recently done in a large Eastern city is typical of this method of construction. An area of sandy and muddy land bordering on a river was chosen for the site of a large warehouse. The plans called for 250 piles in groups of two, three, four, and five, ranging in depth of from 25 to 60 ft. All together this consisted of about 13,000 ft. of piling.

Steel pipe, 16 in. O.D., with $^3/_8$-in. walls was required for this work, and was bought in random lengths, some of it scrap pipe, to be delivered by the pipe dealer ready for driving.

The pipe was delivered in the necessary quantities in short lengths, and double lengths. An oxyacetylene cutter was employed on location to cut off short ends in order that exact measurements could be had. As the pile driver itself would handle pipe lengths only up to 35 ft., it was necessary, where 50- and 60-ft. piles were required, to drive in short lengths of pipe at first. In these cases, a short hollow connecting wedge, barrel-like in shape, was used as a connection for starting the longer sections. Then the steam hammer drove the pile down through the earth to the rock. This was accomplished rapidly by using a hammer that would deliver fast, successive 8000-lb. blows.

That both the oxyacetylene cutting process and the newer oxyacetylene process known as Lindewelding were used for this work is ample demonstration of their ability and worth. It should be remembered that the steam hammer of the pile driver struck hundreds of 4-ton blows on each 35-ft. section of pipe, and that the pipe or joint never failed, even when the pile hit hard rock bottom.

Welded Bomb Bodies Withstand Impact Tests

✦Reprinted from January 21, 1932 issue of *The Iron Age*.

BOMB bodies manufactured by welding forge steel nose and tail sections to the cylindrical body, which is made of a single piece of plate steel welded longitudinally, were tested recently by the United States Army at the Aberdeen Proving Grounds in Maryland. All welding was done by the automatic metallic arc process at the plant of the A. O. Smith Corp., Milwaukee.

Demolition Bomb with Fin Assembly, Showing Welded Circumferential Seams.

Demolition Bomb after Impact on Hard Surface. Dropped from an Altitude of 5000 ft.

The object of the test was to determine the strength of the 100-lb. demolition bomb T3 when dropped on standard hard surface. The bombs were weighed empty, loaded with sand, equipped with tail impact pressure gage and again weighed. The cannon pressure cylinders were measured before and after impact of the bomb. Seven bombs were dropped from an altitude of 4000 ft., others from an altitude of 5000 ft., and several were dropped from an altitude of 2000 ft. After impacts, the bombs were recovered from the hard surface, photographed and the bodies examined for deformation and cracks. The flight of the bombs was observed from the airplane and from the ground.

Both the longitudinal and circumferential welds on all bombs withstood these standard hard-surface tests; none of the bomb bodies showed any signs of cracking or splitting open on impact. There was no perceptible difference in the amount of deformation in the bomb bodies dropped from 4000 ft. and those dropped from 5000 ft. The flight of all bombs was especially good.

The Use of Steel Castings in Welded Structures

By J. G. RITTER

†Paper delivered before a Meeting of the Steel Founders' Society of America, Chicago, January 20-21, 1932, by J. G. Ritter, Welding and Foundry Engineer, Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.

THE USE of welding in the construction of machinery parts has increased very rapidly in the last few years. Welding can now be considered as fundamental a process as riveting and casting for making products of metal. The Westinghouse Company is a large user of welded structures, castings, and structures formed by combinations of castings and welded steel. Over 1000 tons of welded structures are manufactured a month in spite of the fact that the company operates

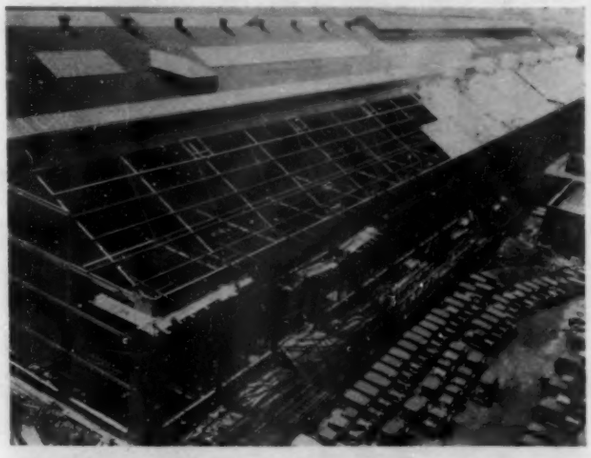


Fig. 1—Welding Building

five iron foundries and one steel foundry. Figure 1 shows the welded building in which most of the welded structures are made.

The experience of the last few years has established quite definitely the economical dividing lines between the different methods of construction. The relative cost of a riveted to welded structure is quite easy to determine, being largely a comparison of the actual cost of the riveting operation to the welding. Riveting has been practically eliminated even in departments which had elaborate riveting equipment. The comparison of the cost of welded structure with a casting becomes much more complicated, especially when the manufacturer operates a foundry. In general, the most important factor involved is the number of pieces which are to be made. If there are only a few pieces the saving of the cost of a pattern usually insures a cheaper construction in welded steel. Figure 2 shows a bearing pedestal of welded construction which can be more economically made by casting it if more than four of one design are needed.

When the activity is high the pattern does not affect the cost comparison very much. The pattern cost is usually about the same as that of the jigs and special

Fig. 2—Bearing Pedestal

tools required for the high production of welded structures. It has been established that bedplates of welded construction are the most economical regardless of the quantity involved. This is due to the fact that this type of structure has a relatively small amount of welding and fitting for the weight involved. They are constructed of standard rolled shapes, cut to length and fitted with very little labor and waste material. This is contrasted with the motor frames of other types which are constructed by burning annular rings from a plate with quite a high labor cost and scrap ratio.

There is another factor other than cost which is often involved when deciding on which form of construction is to be used. This factor is the question of quick delivery and the welded construction has the advantage here.

In general, the welded structure does not have as great an advantage over steel castings as it does over iron castings. This is due to the fact that cast steel is equally as strong as the rolled steel used in welded construction. When replacing an iron casting the welded construction can be made much lighter and the welds do not have to be very large in order to give a structure comparable in strength. In steel, however, the design has to be followed almost exactly and the welds have to be large enough to develop the full strength of the steel sections. The direct current motor rotor shown in

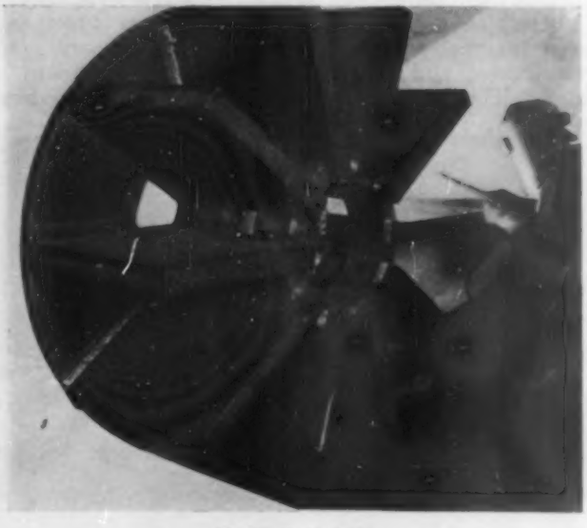


Fig. 3—D. C. Rotor

Fig. 4—Welded Diesel Part

Fig. 3 is subjected to very high stresses, being used on steel mill reversing mill motors. Welded construction is the most economical for this type of design except on the smaller sizes which are made of cast steel. It was found to be more economical to make the lower piece, or bedplate of a 350 H.P. high speed railway diesel engine of welded construction (see Fig. 4). The design consisted mostly of flat thin walls which made their

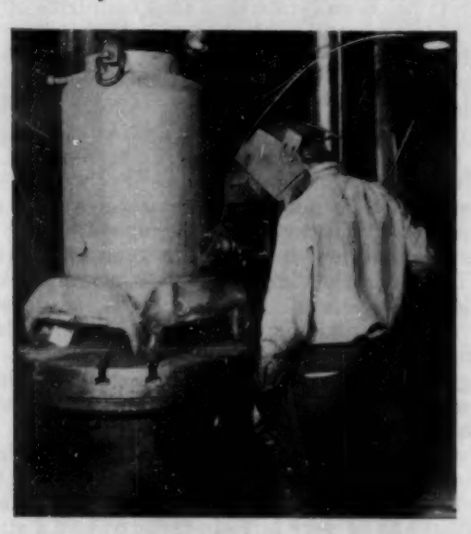


Fig. 5—Circuit Breaker Tank

replacement with plate construction fairly simple. There are so many intricate shapes in the upper casting that it was not found feasible to weld it even if combinations of castings, forging and rolled plates were used.

Very often the cost of a welded structure is increased very materially because some parts of it are quite complicated and require a relatively large amount of labor. The logical thing to do here is to construct

Fig. 6—Bearing Guide Bracket

these parts of steel castings and then weld them in place. Cast steel with a carbon content of 0.30 per cent and under can be welded as successfully as the rolled steel. Higher carbon and alloy steels can be used if the proper welding procedure is used.

Fig. 7—Welded Turbine

Figure 5 shows a circuit breaker tank with a cast steel ring being welded to its top rim. Various pockets and brackets are combined into the single casting. It is machined and drilled complete and then welded to the tank. The tank is rotated by the turntable shown

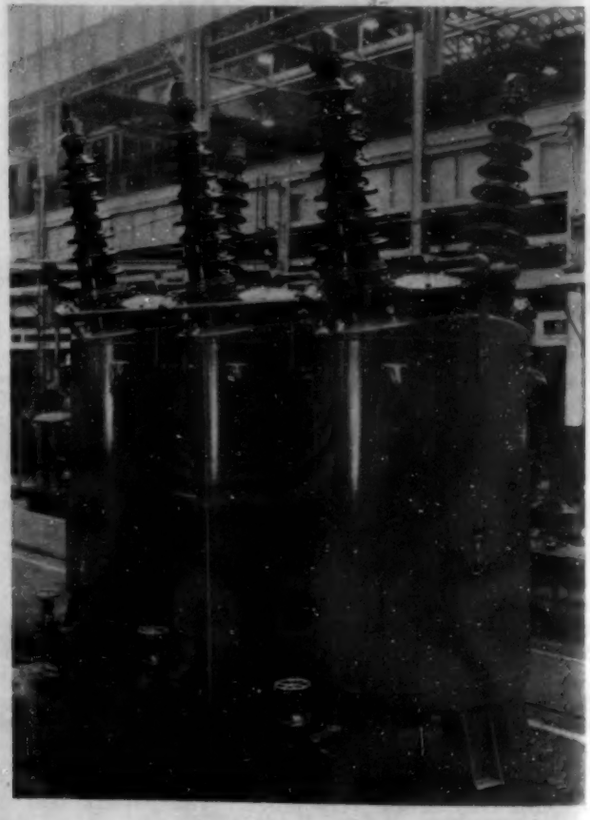


Fig. 8—Lifting Hooks Welded on

Fig. 9—Gyroscope

and the weld deposited by the automatic welding head. This form of construction insured a good gasket fit for the top as well as low manufacturing costs.

A combination of a large fabricated structure with steel castings is shown in Fig. 6. This apparatus carries the lower guide bearing of a large waterwheel generator. The guide bearing is supported by the four steel castings which are welded to the beams in the center of the structure.

In making welded steam turbines there are several points where castings are used to advantage. Some of the parts with cored passages are cast and then welded to the rest of the structure as shown in Fig. 7.

Lifting lugs are used on a great variety of apparatus. By making them of steel they may be welded in place at a much lower cost than riveting or bolting. Figure 8 shows a typical lifting hook.

The apparatus shown in Fig. 9 is the main frame of a gyroscope which is used to control the oscillations of a large ship. The main trunnion supports are steel castings welded to the main fabricated structure.

Welded construction has unquestionably taken a definite place in machinery construction but there is no doubt but that some of the features which make it economical can also be used to lower foundry costs. The welded designs are inherently simple with straight sides, small radii at corners, few holes and other features which would lower pattern and moulding costs.

The recent increase in the use of welded structures is due to the data on improved welding methods and design suggestions which have diligently been called to the attention of engineers. Foundry practice is so old that it has been more or less taken for granted, and a great deal of benefit would be derived if more attempts were made to assist designers with suggestions enabling them to take advantage of modern foundry methods.

Rules and Regulations for Electrically Welded Steel Constructions in Germany

By Naval Arch. P. V. JANKOV

Oslo, Norway

NEW RULES on welded steel construction have been published under the title, "Vorschriften fur geschweisste Stahlbauten."

Explanations to these rules with examples for calculation of welded construction have also now been prepared by Dr.-Ing. O. Kommerell and published by Wilhelm Ernst & Sohn.

The rules are the product of cooperative work of representatives of the Government and of associations of the producing industry.

This work was in charge of a technical committee on welding under the Verein Deutscher Ingenieure.

Dr.-Ing. O. Kommerell in his explanations takes successive sections of the rules and gives his comments and interpretations in the first two chapters of the book.

As the basis for calculation of welded constructions rests on the experience gained from tests, Dr.-Ing. O. Kommerell refers in the third chapter of his book to some specimens of welded constructions built and tested at the Technischen Hochschule in Dresden. This chapter is the most interesting for welding engineers, because it shows that with the prescribed value of allowable stresses and safety coefficients constructions can be designed good and suitable for the various purposes.

The table below shows results of one of the Dresden

No.	Arrangement of Welded Joints	Allowable Load P_A	Ultimate Load P_B	Safety Coefficient	P_B in Relation to I Cm.³ of Welded Joints
		Kg.	Kg.		Kg.
1		5620	28,000	4. 98	1220
2		7400	38,200	5. 15	885
3		3050	14,500	4. 75	450

tests, and one can see that specimen No. 2 gives the best and the third one, with connecting angles, the worst results in all respects.

The fourth chapter deals with some examples regarding calculations of welded joints and shows how the rules may be applied to get safer and at the same time simpler constructions.

Of great importance to welding engineers are some remarks about supervision, and where and to what extent it is of advantage to apply the electrical welding.

Unfired Pressure Vessel Code

Editorial Note: In the January issue there was published the Revised Rules of the A. S. M. E Boiler Code relating to welding. It has been suggested that we reproduce paragraph U-20 relating to values of S at various temperatures. This is reproduced herewith.

U-20. *For Internal Pressure.* The maximum allowable working pressure on the shell of a pressure vessel shall be determined by the strength of the weakest course computed from the thickness of the plate, the efficiency of the longitudinal joint, the inside diameter of the course, and the maximum allowable unit working stress.

$\frac{S \times t \times E}{R}$ = maximum allowable working pressure, lb. per sq. in.

where S = maximum allowable unit working stress in lb. per sq. in., taken from Table U-3.

t = minimum thickness of shell plates in weakest course, in.

E = efficiency of longitudinal joint or of ligaments between openings

for riveted joints = calculated riveted efficiency

for fusion-welded joints = efficiency specified in Pars. U-68, U-69 and U-70

for seamless shells = 100 per cent

for ligaments between openings, the efficiency shall be calculated by the Rules given in Pars. P-192 and P-193 of Section I of the Code.

R = inside radius of the weakest course of the shell, in., provided the thickness of the shell does not exceed 10 per cent of the radius. If the thickness is over 10 per cent of the radius, the outer radius shall be used.

NOTE: When the allowable efficiency of the joints is not given, the values for $S \times E$ for the maximum unit joint working stress at right angles to the direction of the joint given in Pars. U-70, U-82 or U-94 shall be used.

Table U-3—Values for *S* at Various Temperatures

Max. Temp., Deg. Fahr.	Minimum of specified range of the tensile strength of the material, lb. per sq. in.				
	45,000	50,000	55,000	60,000	75,000
700	9,000	10,000	11,000	12,000	15,000
750	8,220	9,110	10,000	11,200	13,000
800	6,550	7,330	8,000	9,000	10,200
850	5,440	6,050	6,750	7,400	8,300
900	4,330	4,830	5,500	5,600	6,000
950	3,200	3,600	4,000	4,000	4,000

This table applies to all plain carbon steels for which specifications are given in the Code. Where the minimum tensile strength of the specified range or the temperature differs from those for which values are given in the table, the values for S for such materials may be determined by interpolation.

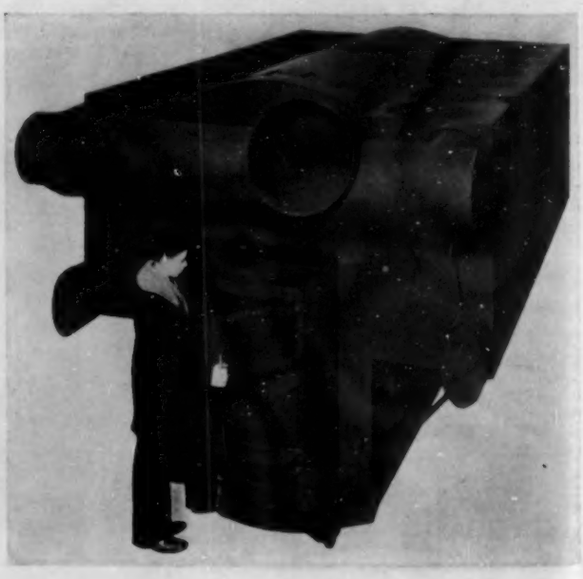
The Largest Warm Air Furnace in the World

By **A. F. DAVIS**

✦ Mr. Davis is vice-president of the Lincoln Electric Co.

THIS large furnace, fabricated by the arc welding process, was built by the Campbell Heating Company of Des Moines, Iowa, for a large church in Rochester, Minn. It weighs 10,000 pounds, has a capacity of 100,000 B. t. u.'s, and contains over 482 feet of electric welding.

The shielded arc was used in the fabrication of this huge furnace.



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